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AIR FORCE

HUMAN RESOURCES

COMBAT-READY CREW PERFORMANCE MEASUREMENT SYSTEM: PHASE I MEASUREMENT REQUIREMENTS

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December 1974

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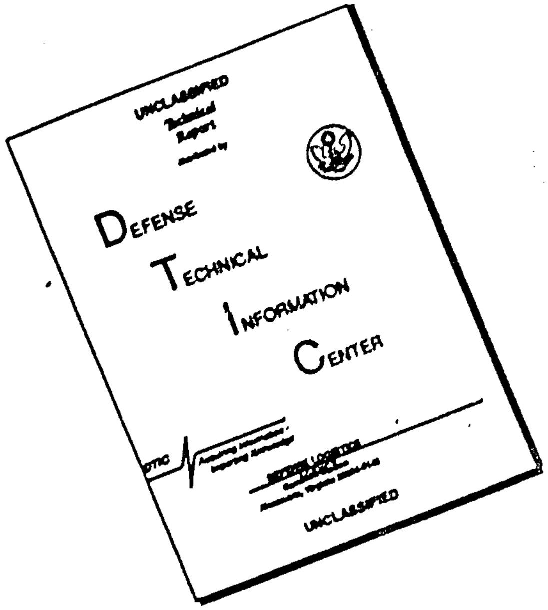

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This technical report has been reviewed and is approved.

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Approved for publication.

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Research for the improvement of combat-crew training, and the efficient execution of current training programs, are heavily dependent upon good sources of information about trainee performance during and at the end of training. In an effort to improve training performance information, this study is directed to systematic definition of performance and development of methods for measurement. The primary goal of this study is to provide usable measurement tools for attacking problems related to combat-crew training.

The first phase of this program is devoted to the definition of requirements for information based on data-collection surveys to six selected combat-crew training sites (A-7, B-52, C-130, C-141, F-4, F-106 weapon systems).

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PREFACE

This interim report was produced as a result of the first phase of a study under Contract F41609-71-C-0008, entitled "Research on Operational Combat-Ready Proficiency Measurement." This contract was performed by Manned Systems Sciences, Inc., Northridge, California, for the Flying Training Division, Air Force Human Resources Laboratory (AFSC), Williams AFB, Arizona. Major J. Fitzgerald, Chief, Combat-Crew Training Branch, was the contract monitor. The first phase occupied three months of an 11-month, three-phase study; Phase I was completed on 31 March 1971.

This report is one of a series of seven reports constituting the Final Report of Contract F41609-71-C-0008. These reports are listed below:

Combat-Ready Crew Performance Measurement System:

AFHRL-TR-74-108(I): Final Report

AFHRL-TR-74-108(II): Phase I. Measurement Requirements

AFHRL-TR-74-108(III): Phase II. Measurement System Requirements

AFHRL-TR-74-108(IV): Phase IIIA. Crew Performance Measurement

AFHRL-TR-74-108(V): Phase IIIB. Aerial Combat Maneuvers Measurement

AFHRL-TR-74-108(VI): Phase IIIC. Design Studies

AFHRL-TR-74-108(VII): Phase IIID. Specifications and Implementation Plan

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COMBAT-READY PILOT PERFORMANCE

MEASUREMENT SYSTEM STUDY

I. INTRODUCTION

Research for the improvement of combat-crew training, and the efficient execution of current training programs, are heavily dependent upon good sources of information about trainee performance during and at the end of training. In an effort to improve training performance information, this study is directed to systematic definition of performance and development of methods for measurement.

The point of view taken in this study is that measurement is the means of providing information needed by training research scientists and operational training personnel. The primary goal of this study is to provide usable measurement tools for attacking problems related to combat-crew training.

It is necessary at this time to place emphasis on the measurement of pilot performance, although it is recognized that it is often not possible to separate pilot from crew/system performance. It is anticipated that future efforts will be directed to the total problem of all measurement related to each individual and collective contribution to overall mission achievement.

The first phase of this program is devoted to the definition of requirements for information based on data-collection surveys to six selected combat-crew training sites (A-7, B-52, C-130, C-141, F-4, F-106 weapon systems). The second phase concludes in a conceptual design for a feasible class of measurement systems. Subsequent efforts are devoted to design/tradeoff studies and preparation of specifications. The end goal is the specification of a measurement system including the information, devices, personnel and procedures to define a usable system which will produce the information needed for training research efforts.

This report documents the activities and findings of the first study phase. The other phases of the study will be documented in subsequent reports.

GOAL: SPECIFY A USABLE MEASUREMENT SYSTEM

The basic goal of this study is to produce a tool needed for meaningful research. This study will specify a measurement system that is usable and useful for the resolution of operational training problems. It is understood that the measurement problem has been with us for some time, and that many other attempts at solving the problem have been made. It is not the

goal of the current activity to solve all measurement problems--that is judged to be unrealistic--however, the current measurement problems will be defined to permit application of the state-of-the-art in measurement techniques and engineering to the production of usable, meaningful information.

Identify standards for a systems approach to training. A reason for concentrating on problems of measurement at this particular time is the present emphasis on instructional system development. Instructional system development requires that performance standards are identified so that the most efficient approach is used to train the needed skills and knowledge to the desired level of performance. Such performance standards imply performance measurement for both the determination of desirable approaches to training and for testing student performance.

It is hoped that no confusion between the current study and the systems approach to training will occur. This study is an application of the systems approach, but to the design of a measurement system, not a training system.

Produce an operationally feasible information system. While the basic goal is to produce a tool for the conduct of training research, it is desired that the measurement system defined in this contract be suited for the collection of data in the combat crew training environment. Wherever the state-of-the-art will permit, a measurement system requiring a laboratory environment will be avoided.

Support meaningful research. For research to be meaningful to the operational training problem, the measurement taken must provide information meaningful to both the research scientist and operational training personnel. At one extreme, if research addresses performance which is not important to the weapon system mission, then such research can hardly have operational relevance. The problem of collecting meaningful information in research is discussed more thoroughly in the following section.

MEASUREMENT: A MEANS FOR COMMUNICATION

Figure 1 presents a very simplified view of the functions of the Instructor/Training Manager and the Training Research Scientist. The Instructor and Training Manager control a training process. To do this they must have information about the performance of the student in order to exert instructional control. The information which is used for instructional control is the focal point of the current contract. While such information may be collected quite informally in the instructional process, a measurement system would collect the same information in a more formal, explicit manner.

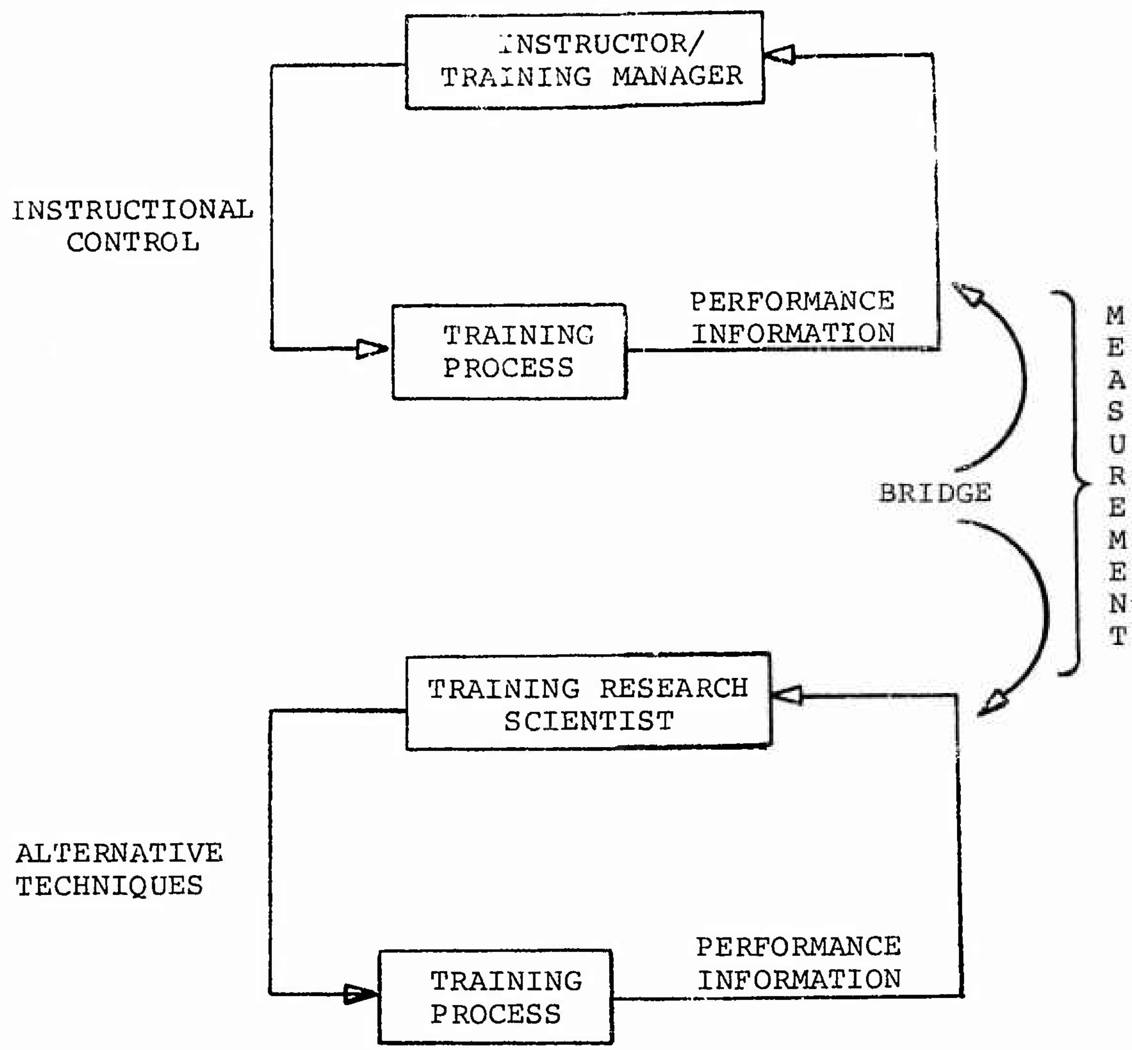


Figure 1. Measurement, A Means for Communication

Presented in this simplified manner, the Training Research Scientist performs a similar role. He collects performance information from the training process in an attempt to evaluate the training techniques which are administered.

A strategy employed in this program is to define the performance information used in the combat-crew training environment based on data collection trips, then use the definition which was possible to construct performance measurement for use in training research. As a result of this approach, measurement for both situations should agree in large measure. If the Instructor/Training Manager and the Training Research Scientist collect the same information, that is, measure in the same way, the measurement will provide a common language for communication. Without common measurement, communication will be difficult, and, it will be difficult for meaningful research to be conducted to relieve the problems encountered in combat-crew training. Measurement can provide the "bridge" to connect training research with operational solutions.

PROGRAM STRUCTURE

This study is an application of the systems approach to the design of a measurement system to produce information relevant to combat-crew training. See Figure 2 for a program flow diagram.

The initial program phase is devoted to a definition of the requirements appropriate to such a measurement system. The requirements are established by determining the information useful and meaningful for combat-crew training, and the requirements imposed by anticipated research topics.

Based upon established requirements, consideration will be given to the variety of possible systems and to the known constraints. A conceptual design consisting of feasible alternatives will be generated, indicating the type of information possible, the places where such information will be useful, and the possible ways such information can be collected.

A variety of alternate systems will result from the conceptual design. These require analysis to further define the details of implementation, and the nature of the tradeoffs to be considered in selecting measurement systems. Through analysis, a measurement system will be selected with broad application. Such a measurement system must be quite inexpensive in comparison with the benefits to training which will be derived.

Through the above stages of analysis, a specific system most directly useful as a research tool will be identified. For this system, specifications are then prepared to define sufficient detail to implement the system. The specifications thus must include hardware descriptions, measurement definitions

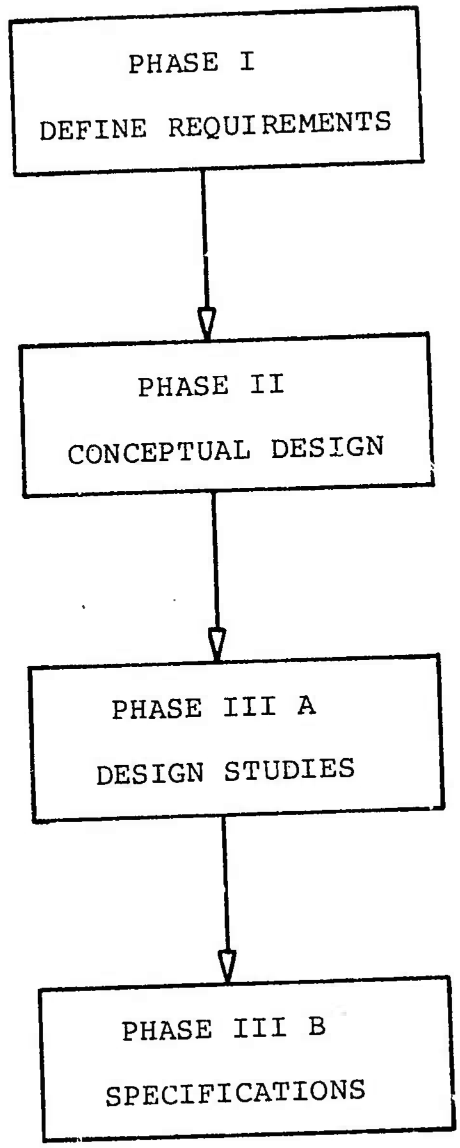


Figure 2. Program Sequence.

and other software, data handling equipment, procedures and personnel. A total measurement system will be defined, which, it is assumed, will be configured for test and experimentation prior to any major use for training applications.

Current stage. At this time the requirements for a measurement system have been defined, although it is expected that the statement of requirements will continue to be refined throughout the remainder of the program. A survey of those places, where information about combat-crew training requirements is available, has been accomplished, namely, at combat-crew training squadrons. The information sought was available in most cases; however, additional analysis and correlation between sources was necessary to present the type of data desired. Since a primary requirement was the development of a research tool, the measurement requirements were established with these needs in mind.

This report, therefore, documents the product of the Phase I study effort. It should be noted that much of the study remains to be accomplished. The current report consists of three main topics:

(1) Data collection efforts at combat-crew training sites. To maximize the utility of site visits, data were collected for the entire study to the degree possible; thus, data were collected beyond the definition of requirements, including data for the development of specific measures.

(2) Analysis of common measurement requirements. To be tractable, and to lead to a practical approach to measurement, some common requirements for training information must exist across the six weapon systems examined.

(3) Dimensions of measurement modularity. To permit a modular approach to measurement, i.e., a building block approach to a specific application, the dimensions of the problem must be identified in a manner suggesting measurement system characteristics.

These topics are discussed in the following chapters.

II. COMBAT-CREW TRAINING DATA COLLECTION

A range of combat-crew training environments were visited. Approximately one week was spent at each of six sites collecting as much data as feasible for the current program. At each site, the existing measurement and the potential for measurement was noted. Opportunities for the collection of research data were observed, and data collected for the development of new measurement.

COMBAT-CREW TRAINING SQUADRON VISITS

It was desirable for the purposes of this study to sample the range of combat-crew training currently existing in the United States Air Force. Consequently, the sample included heavy and high-performance aircraft. Within heavy aircraft, cargo, transport, and bomber types were considered; and, within high performance aircraft, interceptor and fighter-bomber types were considered.

While a broad sample is needed, such breadth brings along with it a number of differences which should be noted. Such a sample is quite heterogeneous in many ways, making it difficult to present a uniform set of observations. Table 1 shows the specific combat-crew training sites visited and some of their differences.

The only site visited which actually trained combat-ready pilots was the C-130 school at Dyess AFB, Texas; however, generally discussions of combat-ready performance were possible at all sites visited. At Tyndall AFB, Florida and Luke AFB, Arizona, experienced pilots were converted to new aircraft and graduated as mission/combat capable. In these cases, the graduate is very nearly ready for combat. At Davis-Monthan AFB, Arizona, graduates of the Undergraduate Pilot Training curriculum are trained to mission-capable status; these F-4 pilots should also be nearly ready for combat. Undergraduate Pilot Training (UPT) graduates are trained to co-pilot qualified status at Castle AFB, California, and Altus AFB, Oklahoma. In all cases, a variety of student types may be trained, ranging from UPT graduates to seasoned pilots.

Those graduated as mission capable or combat capable will require a moderate amount of subsequent training and a flight check in the operational unit to which they are assigned; they may require training for specialized roles. Those who are initially qualified as Co-pilots may fly for a number of years before being upgraded to Aircraft Commander, although the requirements for upgrading are currently being reduced. While such Co-pilots may require considerable training before upgrading to Aircraft Commander, they nevertheless may require relatively little training to serve as a combat-ready Co-pilot.

TABLE 1

SUMMARY OF SITES VISITED

PLACE	A/C	TRAINING PRODUCT
Castle AFB	B-52 F, G & H	Co-pilot qualified
Altus AFB	C-141 A	Co-pilot qualified
Dyess AFB	C-130 E	Combat-Ready Crew
Davis-Monthan AFB	F-4 C, D, E	Undergraduate Pilot Training to F-4 mission capable
Tyndall AFB	F-106 A & B	Prior Interceptor experience to F-106 mission capable
Luke AFB	A-7 D	Fighter pilot conversion to A-7D combat capable

The use of the terms "mission-capable", combat-ready", technically involve specific exposure to training and operational experience. However, specific levels of proficiency are implied, which it is one of the objectives of this study to further define.

DATA COLLECTION METHOD

At each combat-crew training squadron all existing subjective and objective methods of measuring performance, during and at the end of training, were examined. The types of data sought are presented in Table 2. The general categories of information sought are: (1) training program description and measurement included in the formal training program, (2) information which can be characterized as meaningful and most important for each phase of training, and (3) opportunities for measurement which are presented during the course of training in the various devices used for training, and, resources which may be available for data handling. While it was desired to derive information directly from experts to the extent possible, documentation and references were also collected wherever available. In short, it was attempted (1) to properly consider measurement in the context of combat-crew training, (2) to assess the measurement already included as well as potential measurement indicated by combat-crew training personnel, and, (3) to assess the constraints placed by the combat-crew training environment on feasible, usable measurement systems.

TABLE 2

DATA SOUGHT

TRAINING PROGRAM MEASUREMENT	
	Grades (info. used for)
	Standards & Eval.
	Scoring
MEANINGFUL INFO. IN EACH MAJOR TRAINING PHASE	
	Important Parameters
	Judging Factors
	Common Errors
POSSIBILITIES FOR MEASUREMENT	
	A/C & Systems
	Training Devices (Simulator)
	Data Handling Resources
	Use & Timeliness of Data for Training

Data sought. Each training program was examined to determine the flow of training and the points at which measurement take place. The grading structure was discussed, although interest was primarily in the information used to determine grades, rather than the specific grades or their use. Scoring of any specific training events was specifically noted (e.g., weapons delivery scores). The Standardization/Evaluation program in use was discussed to determine performance standards in use, and the administration of Stan/Eval testing. The use of trend analyses and the standardization of instructor evaluation criteria were noted.

Data collection included academic, simulator, and flying training. For each major mission (e.g., transition, instruments, etc.) instructor interviews were held to uncover data related to measurement of performance. In particular, the parameters held to be important, the factors used in judging student performance, and common student errors, were documented. It was attempted to

determine those kinds of information thought meaningful to the instructor for assessing performance throughout the course of training. Common errors indicated areas where emphasis in measurement is needed. Parameters of importance indicated items for measurement, while the factors used by instructors in judging performance helped to define criteria in use.

To assess the potential for additional measurement, the aircraft and its systems, and training devices, were examined for existence of measurement devices or the possibility for attaching new measurement devices. The use of data, and required timeliness, were examined wherever specific measurement items could be identified. Resources for data handling, such as computer facilities, were noted wherever possible.

Examples of useful information. The data collection activity was tailored to the particular training and weapon system employed at each training site. Examples of desirable information are presented in Table 3. Documents were desired in as much quantity as was practical. Documents described the systems and the measurement possible, and also provided sufficient background in the missions taught to allow the study team to become more knowledgeable in the context where measurement may be applied. To the extent that documents could reasonably replace discussion, this was done; however, expert judgment and opinion generally supplemented text materials. Expert judgment indicated measures of importance, the manner in which the information would be used, and the form in which it would be useful. Finally, some exposure to samples of the training environment and training materials was useful in conveying a context and specific information to the study team for the development of measurement suitable to the combat crew training needs.

Example week's activities. The schedule was outlined on the first day of a visit at a Combat Crew Training Squadron. However, Figure 3 is presented as a typical schedule.

To derive sufficient information of the type which has been indicated to the depth which is appropriate, was quite difficult to do within the period of a week. While intensive data collection was desired, it was normally possible to arrange a schedule so that no one person devoted more than one or two hours. Of course, the schedule was adjusted to the personnel and individual time which could be made available.

An initial group briefing was useful in organizing the appropriate schedule with the following typical attendance: Training Staff, Educational Specialist, Stan Eval, Instructor Pilots, Academics, Weapons Mission Specialist, Simulator Specialist. A meeting at the end of the week for review and debriefing was normally appropriate and useful.

TABLE 3

EXAMPLES OF USEFUL INFORMATION

DOCUMENTS: T.O. -1, Syllabus and Phase Manuals/ Instructor Manuals, Briefing Materials, Stan/Eval Manuals, Simulator Description, Selected Texts, Examinations, Common Errors, Instructor Tricks-of-the-Trade, Grade Sheets, Examples of Studies & Measurement Conducted.

DISCUSSIONS: Course/Measurement Overview - Education/Trng Staff

: Standards/Eval - Stan Eval

: Each Flying Training Phase - Instructor Pilots

: Major Missions - Academics

: Use of Simulators & Other Training Devices - Instructors

: Weapons/Mission Scoring

: Need for & Use of Measurement - Instructors/Staff

EXPOSURE : Simulator Training

: Mission Briefings

: Demonstrations

Monday	Tuesday	Wednesday	Thursday	Friday
Group Briefing	Flying Phase -IP ——— Flying Phase -IP	Flying Phase -IP ——— Flying Phase -IP	Weapons/ Mission Scoring ——— Simulator Tr. Device Construction	Review & Debrief Staff-Weeks Acitivities
Overall Program Discussion ——— Standards Eval.	Academics General Discuss. ——— Academics -Major Mission	Academics -Major Mission ——— Academics -Major Mission	Observe/ Discussion Briefing & Training in Simulator	(Time Used as Needed)

Figure 3. Example Week's Activities
(For discussion purposes only)

TRAINING MEASUREMENT

At each combat-crew training site visited, information was collected with respect to (1) the training sequence, (2) points where measurement exists, (3) measurement possibilities, (4) feasibility of research measurement, and (5) specific new-measurement development.

Basic training sequence. Of course, each combat-crew training structure was different. However, for the current discussion we can simplify each to a basic training sequence (as shown in Figure 5): Academics, Simulator and Flying Training. In some cases, the sequence is almost precisely as that shown, but in other cases, academics, simulator and flying training are integrated together in a different fashion for each segment of training.

Existing measurement. Formalized measurement for each phase of training is annotated in Figure 5. However, a great deal of information for training is gleaned in an informal way. Since for all of the training examined an instructor was almost always available to observe a student's performance, most of the information gained during non-academic training was quite informal. During a single maneuver an instructor might be forming hypotheses about several aspects of performance, and then subsequently reinforcing or rejecting these hypotheses depending on more observations, or by asking impromptu questions. For the purposes of training measurement most non-academic training is essentially a 1:1 ratio of instructors to students.

Academic measurement normally consists of conventional multiple-choice end-of-course, mid-term and final exams. Only the A-7D program currently uses responder devices (that is, of those visited) to inform the instructor of the general status of the class, and the student of his own performance. The behavioral objectives for academic training are defined in terms of specific knowledge (e.g., name the five system modes, which switch shuts of system X?, etc.); it is believed that this, and ease of administration, accounts for the abundance of multiple-choice tests. A singular exception to this rule is testing for air-air intercept maneuvers. These may show a radar 'scope, and other diagrams, to describe a situation which may take calculation and judgment to arrive at a numerical answer or decision.

Simulator training is often oriented to training of procedures. Frequently, it appears that the simulator would be used for other training, but, unfortunately, either the simulators are very old, or little time is allowed for proper maintenance, precluding the training of tasks requiring a high fidelity of simulation. However, a progress check is commonly given the student during simulation training to determine whether he will be able to advance at a satisfactory rate during later stages of training. Simulator mission briefings and

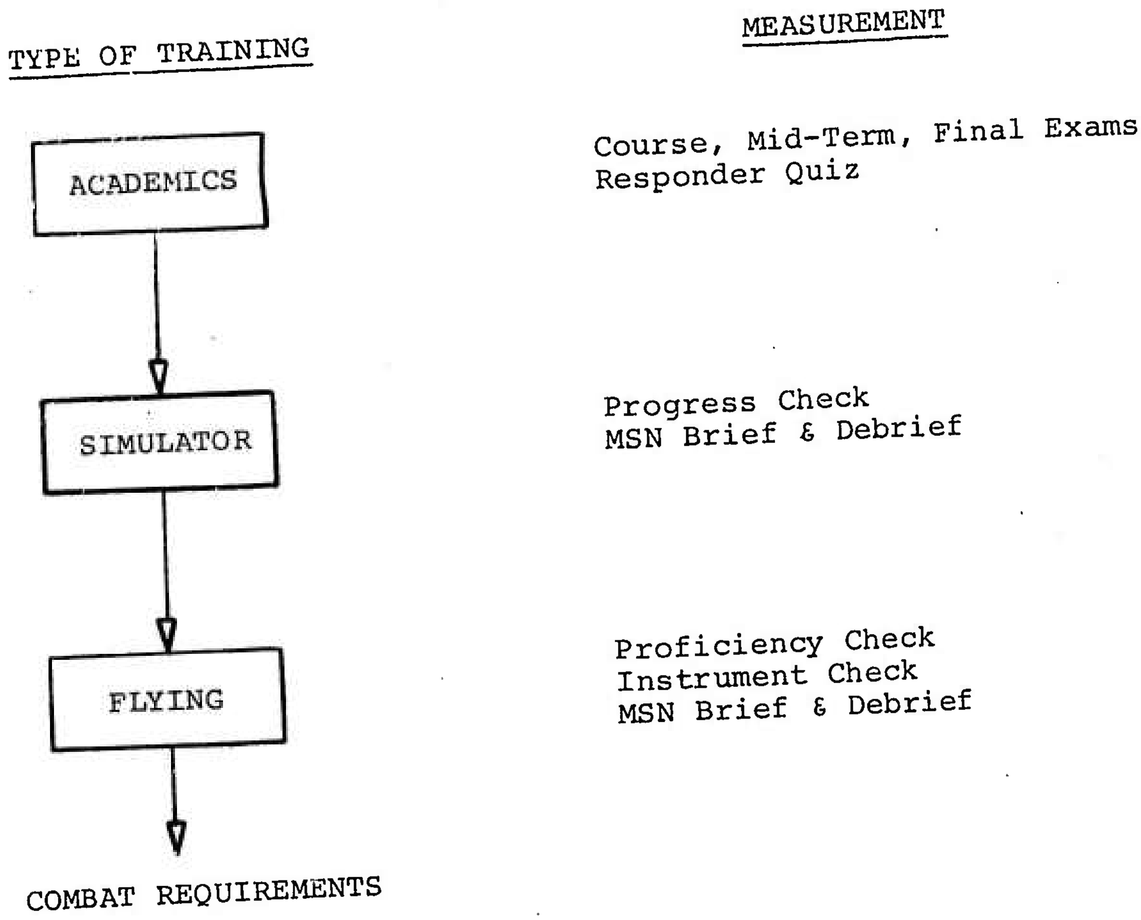


Figure 5. Basic Training Sequence.

debriefings accompany each session, involving complex oral interaction between student and instructor. Measurement at both the academic and simulator training level is often extremely detailed and system specific, involving treatment of almost overwhelming detail to program measurement equivalent to what the instructors do.

A proficiency check is also given during the flying phase of longer training programs to determine whether a student will be able to complete the remainder of training without extensive special treatment. An instrument check is also likely, as most students will become eligible for their annual instrument check; this allows test of instrument proficiency in the specific aircraft to which the student is transitioning. For short courses (initial qualification) a flight check is given at the end of flying training; however, for longer courses an end-of-training flight check may not be given. However, in the latter cases extensive flight-by-flight grading will have been performed. As with simulator training, much training information is collected by informal interaction between student and instructor during briefing, mission, and debriefing. As this study is oriented toward the measurement of combat-ready pilot proficiency, detailed data collection effort for measurement development concentraded on the flying phase.

Opportunities for research measurement. Unless additional measurement time is provided during the current training programs, there are few opportunities for formal measurement. Numerous quizzes are given during academic sessions, mission briefings, and debriefings; however, during those sessions where the student is demonstrating the level of proficiency attained in simulator or flight, the progress check, proficiency check, and instrument check are the only sessions set aside for measurement. Of course, measurement of some sort is taken in all simulator and flight missions, including weapons delivery scores in some. These opportunities for measurement, while few, are placed at important points in the training program, making them quite desirable sources for training information.

It is clear that under the pressures to economize, that time for training is extremely valuable; consequently, the time set aside for proficiency measurement is very precious. If additional time could be allotted, some might be tempted to use such time for training rather than measurement. In fact, much training may take place during current proficiency checks. It would appear that most motivated instructors would rather teach than wash-out a student.

Thus, external measurement during current measurement sessions may not be clearly attributable to the student's performance; much may be due to the presence of an instructor/examiner. It is assumed that research measurement requires assessment of the student's performance uncontaminated by any other influence. Valid measurement depends on such an assumption,

but since the student's performance may be confounded with instructional efforts, collection of research measurement during combat-crew training must be carefully done. Some modification of current programs and procedures may be required to achieve valid research measurement.

III. COMMON MEASUREMENT REQUIREMENTS

Six quite different aircraft were included in the sample for measurement analysis; each of these is capable of flying a number of different types of missions. When attempting to determine whether the design of a simple and practical measurement system for all applications is possible, the question arises as to the degree of commonality among the measurement. Even though aircraft and missions may differ it is conceivable that the measurement system may be relatively similar.

COMMON FLYING PHASES

As a first step to assessing commonality of measurement requirements, the degree to which flying phases are common across aircraft may be examined. Table 4 summarizes the flying phases for each aircraft in comparison to the other aircraft in the sample.

There are artifacts which may enter this analysis which it is hoped are avoided in Table 4: First, not all maneuvers are taught at the sites visited in this study. For example, the operational C-130 squadron visited did not explicitly train transition maneuvers, but it is believed that competent information was obtained for measurement during these maneuvers. The F-106 air refueling modification had not been completed so is not currently trained. Also, all combat maneuvers were not taught at the combat-crew training squadrons visited. Attempts were made to fill these gaps by cross-checking with other aircraft training where similar maneuvers are performed. Secondly, the current analysis is directed toward the measurement of pilot performance. In a single-seat fighter this poses no problems, but where other crew members are available, orientation to the performance of one individual does not completely define the problem. There is, of course, an interaction between the performance of crewmembers in the determination of overall system mission performance. As the current sample consists of aircraft with widely differing crew composition, some maneuvers may appear to be a pilot performance measurement problem in one case, and not be apparent in other cases unless the performance of other crewmembers is considered. A somewhat broader view was taken in this study, and the performance of other crewmembers was considered to the degree possible to properly define common missions.

Transition. For all aircraft examined there is a phase of training termed transition. Transition maneuvers include takeoff, climb, level-off, pattern flight, landings, go-around or low-approach. For some aircraft, acrobatic maneuvers may also be included. However, for the most part, transition maneuvers appear to occur in a common fashion with each aircraft; the question is whether the manner in which they are performed is significantly different for different aircraft. The matter will be discussed in a later section.

TABLE 4

FLYING PHASES

MULTI HEAVY			HI PERF		
B-52	C-141	C-130	F-106	F-4	A-7
TR	TR	TR	TR	TR	TR
INST	INST	INST	INST	INST	INST
-	-	FORM	FORM	FORM	FORM/BFM
			AA	(AA)	
				BFM/ACM	FORM/BFM
AR			-	AR	AR
	-	(AIR DROP)		GA	GA
HI LOW (BOMB)	-	(BEACON DROP)		(GAR)	RNB

LEGEND

TR: Transition
INST: Instruments
FORM: Formation
BFM: Basic Flight Maneuvers
AA: Air-Air Intercept
ACM: Air Combat Maneuvers
AR: Air Refueling
GA: Ground Attack
GAR: Ground Attack Radar
RND: Radar Navigation Bombing
( ): Consider Other Crew
-: Data Not Available At Sites Visited

Instruments. All aircraft must be flown under Instrument Flight Rule conditions. While performance differences exist between aircraft, the instrument maneuvers and the external criteria which must be met, are the same. It is concluded at this point that Instruments is a common flight phase for all aircraft, and that common measurement is conceptually possible.

Formation. Each of the six aircraft are used for military maneuvers involving multiple-ship tactics. Consequently, formation flight is used as a means to optimally employ the composite flight and provide for individual-ship effectiveness. Formation flight is considered to be a common flight phase across aircraft; however, a number of types of formation exist for various purposes, and it is assumed at this point that measurement differences will occur -- especially between multi-engine heavy aircraft and high performance aircraft.

Air-Air Intercept. Air-to-Air Intercept weapons delivery is accomplished only with the F-4 and F-106 aircraft. Some similar intercept activities may occur between radar-equipped aircraft and tanker aircraft for air refueling, but the situation is quite different and the "target" aircraft is cooperatively maneuvering. Thus, the air refueling intercept is considered a different measurement problem at this point. The F-4 and F-106 maneuvers and equipment also differ somewhat but are considered basically the same at this level of treatment.

Basic Flight Maneuvers/Air Combat Maneuvers. Basic Flight Maneuvers and Air Combat Maneuvers are grouped together in F-4 training, while Formation and Basic Flight Maneuvers are grouped together in A-7 training. While F-4 training for air combat is more extensive, the A-7 training elements are common to the F-4; the goal in both cases is to train for aerial warfare with an enemy aircraft. Note, in Table 4, that Formation is combined with these maneuvers for the A-7, as good formation flight is considered a prerequisite for air combat maneuvers, but a distinction between measurement for air combat and formation flight is considered to be defensible.

Air Refueling. Air Refueling can occur with four of the six aircraft (including the F-106), but is only considered a difficult maneuver for the B-52. The other aircraft are high-performance fighters with sufficient maneuverability that this task becomes a special case of Formation. Consequently, we have emphasized air refueling for the B-52.

Ground Attack. A number of training phases are devoted to F-4 and A-7 ground attack: Ground Attack Day (against targets on weapons delivery range), Ground Attack Tactical (against tactical targets), and Ground Attack Night (on the range, at night). While these pose a range of environments for the student

to cope with, these are all considered basically the same task for measurement (i.e., the parameters and criteria are the same). Ground Attack includes delivery of a number of weapon types in different delivery modes. A number of dive angles, including level flight, are used; however, common measurement is probably possible. Also, even though there is some similarity between ground attack measurement and that indicated for transport air drops, quite different measurement may result in this case.

Radar Navigation and Bombing. Navigation by use of radar, and subsequently delivery on a target, occurs with most of the aircraft of the sample. The equipment used is not similar, but the mission performance measurement may be compatible.

Need for Measurement Analysis. In the above, flight phases are grouped together to form a structure for the determination of common measurement requirements. Even where flight phases are very similar it is possible that measurement requirements within a phase are dissimilar; the converse is also possible. Further analysis of the specific measurement required is necessary to determine such commonality.

MEASUREMENT COMMONALITY ANALYSIS

Each phase of flight, tentatively considered to require common measurement, was examined for detailed measurement requirements. An example format for commonality analysis is shown in Figure 6. Each phase of flight was examined for commonality in the same fashion as Takeoff and Climbout; although, some phases of flight, such as Instruments, did not require this detail.

For each maneuver of the flight phase, measurement requirements were extracted from interview notes with Instructors/ Examiners, Tech. Order Dash-One flight manuals for each aircraft, Phase Manuals, Instructor Guides, and other specialized documents. Basically, the information which an instructor pilot would consider important was translated into objective measurement, together with whatever criteria could be specified.

For each block in Figure 6, for Takeoff and Climbout maneuvers, required conditions and tolerances were noted for such items as power, heading, airspeed, altitude, flaps, trim, etc. The similarities and differences noted are discussed below to provide an example of the analysis performed. (Additional discussion is presented in Appendix A.)

Roll. It is desired to hold alignment with the centerline, or whatever displacement from the centerline established at the beginning of the takeoff. The tolerances vary between aircraft, normally 5 - 10 ft. is allowed. Heading should correspond with the runway direction. Power settings required can be specified; however, the parameters vary, e.g., EPR, Fuel Flow, TIT, %RPM, TOP. Bank angle should be zero during the roll.

MEASUREMENT COMMONALITY ANALYSIS

PHASE	MULTI HEAVY			HIGH PERFORMANCE		
	B-52	C-141	C-130	F-4	F-106	A-7
ROLL						
ROTATION						
LIFTOFF						
GEAR-UP						
FLAPS-UP						
CLIMB & LEVEL-OFF						

Figure 6. Commonality Analysis Format for Takeoff and Climbout.

Rotation. An acceleration check is made when the expected length of roll is long in comparison with runway length. Rotation should occur at specific airspeeds, within 1 - 2 KIAS. A particular rotation rate is desirable, and a rotation pitch angle is important for a good takeoff. Bank angle should still remain zero. Setting of the stabilizer trim is important.

Liftoff. Liftoff should occur at a prespecified unstick airspeed; a positive rate of climb should be established without settling.

Gear-Up. The gear must not come up before positive climb is established, and not after critical airspeeds are reached. In some aircraft the time to raise gear is rather short, and in some the gear may blow up at maximum gear speed.

Flaps. Normally, flaps must be raised between a minimum airspeed and a maximum airspeed, and above a specified altitude. These speeds are a function of gross weight. Some distinct differences between aircraft should be noted. The F-106 has no flaps, therefore, no flap-related measurement is appropriate. The B-52 has a complicated flap schedule associated with it; the flaps must be started up at a particular speed and entirely up at another speed; intermediate flap positions and speeds are also measured.

Climbout and Leveloff. Depending on the aircraft and particular profile for a given mission, a number of measures are in order: (1) constant rate-of-climb, (2) constant airspeed, (3) constant pitch angle, and (4) constant mach. Power and trim settings will be important. Each type of climb may be held until conditions are satisfied for initiating another type of climb, e.g., X fpm until Y KIAS, hold Y KIAS until 10,000 ft., hold Z KIAS until 27,000 ft., hold Mach .xx thereafter.

Takeoff and Climbout Commonality. It should be clear that some differences exist regarding takeoff and climbout of the six different aircraft. On the other hand, it should also be apparent that the basic measurement components are the same. At times, some measurement components are present in one case and not in another; at other times, the criteria numbers and tolerances are different. Thus, for Takeoff and Climbout (as for many other maneuvers), the measurement cannot be designed without consideration of the specific aircraft for which it is to be used, but the basic measurement modules are the same, allowing a measurement system to be tailored rapidly given the necessary building blocks. In terms of such a modular definition of commonality, the measurement for Takeoff and Climbout is considered to be common.

PROTOTYPE MEASUREMENT

As a natural extension of the considerations of measurement

commonality, examples of the information required for training were developed in the form of formatted measurement outputs. That is, if a measure of centerline deviation was indicated to be desirable, this would be noted; this process would continue until all known information requirements for a given phase of flight had been recorded. These data would then be assembled into a format to resemble measurement output. Specific measures are not developed at this point; only the need for information is identified. This output is termed here as Prototype Measurement.

Prototype measurement is the first concrete form in the development of measurement. At this point the definition is sufficiently flexible to serve as a model for the measurement for any of the six aircraft considered. Prototype measurement was developed in a few cases during the data collection period for specific aircraft, and used as a strawman in discussions with pilots. This form appears to provide a good vehicle for communication with regard to measurement as well as being a development tool.

The prototype measurement produced is presented in Appendix A for the following:

Takeoff & Climb
Pattern, Land or Go-Around
Instruments - General
Instruments - Example
Formation
Intercept
Air Combat Maneuvers
Air Refueling
Ground Attack
Air Drop
Air Drop Formation
Radar Nav. Bomb

Prototype measurement for Takeoff and Climbout is presented in Figure 7, as an example.

Measurement Complexity. Examination of the prototype measurement will reveal that the measurement requirements are very extensive and complex. However, even these examples belie the true extent of the complexity. Any one of the blanks in these forms can pose a difficult measurement problem; each blank can be amplified into a number of measures to fully respond to the information needs indicated. It may be seen that to describe just Takeoff and Climb may require the measurement of 50 - 100 numbers. If full mission measurement is attempted, including transition, instruments, formation, and weapons delivery, a very large set of descriptive numbers will be needed.

This detail is very probably needed to support the training process. The instructor may need considerable detail to perform

TAKEOFF & CLIMB*

CONDITIONS:

Gross Wt: _____ Wind: ____/____ Runway: ____/____ Temp.: _____
Alt. Set.: _____ Fld. Elev.: _____ Form Pos.: _____

TAKEOFF ROLL: (TO power until rotation)

Power Set: _______ Centerline Dev: Min, Max, Av.
Reject Speed: Computed Heading: Min, Max, Av.
Time: _____ Dist: _____ Bank: R Max, L Max

ROTATION: (Nose gear off until pitch att. established)

Rot. Speed ____________ Stab. Trim: ____________
Pitch: Rate: __________ Bank: ____________
Final: _________ Centerline Dev.: _______
Overshoot: _____ Heading: ____________

LIFTOFF: (Pos. Vert. Vel.)

Unstick Speed: _____ Pitch: _____ Bank: _____ Hdg: _____
Vert. Vel. After: _____ Sec.: _____

GEAR-UP: (Handle up until gear-up & locked)

Gear-Up Speed: _____ V.V. Init.: _____ V.V. Final: _____
Pitch: _____ Bank: _____ Hdg.: _____

FLAPS UP: (Start up to full up) Note: F106 has no flaps

Trim: _____
Pitch : _____ Bank: _____ Hdg.: _____
A/S (INIT) _____ (FINAL) _____
VV (INIT) _____ (FINAL) _____
ALT (INIT) _____ (FINAL) _____

B-52 Only	IAS	PITCH	ALT	VV	TRIM
Start	x	x	x	x	x
1st Pos	x	x	x	x	x
2nd Pos	x	x	x	x	x
Full	x	x	x	x	x

CLIMB & LEVEL-OFF: (Depends on Flight Plan)

	PWR	A/S	MACH	HDG	INIT ALT	FINAL ALT	PITCH	TRIM
Accelerate	x	x	x	x	x	x	x	x
Climb A/S (#1) (#2)	x	x	x	x	x	x	x	x
Climb Mach	x	x	x	x	x	x	x	x
Level-Off (Alt-10% VV) (to Cruise)	x	x	x	x	x	x	x	x

Figure 7. Example Prototype Measurement.

*Also, mandatory communication & instances where A/C limits are exceeded.

his job well. However, if the purpose is to evaluate for the purpose of research, a much simpler approach may be needed. The data process task of statistically analyzing such an extensive array of numbers across a number of subjects and trials is formidable; the task of interpreting these data for research implications may be infeasible.

These information requirements may be filtered for research measurement development. The level of measurement is, however, probably necessary for many training purposes, as this is the source of the information. Figure 1 indicates that the basic strategy was to examine the performance information needed for training to derive common performance measurement for research application. However, a subset of the training information needs may suffice for research evaluation. For example, for Takeoff, conditions at liftoff and general measures of takeoff-roll may suffice; for landing, speed and altitude at threshold, distance down the runway for touchdown and stopping, and centerline deviation throughout, should suffice. The determining factor of the measurement needed for research is the information needed; it is believed that the information needed for training establishes a complex level of proficiency measurement. Of course, specific research may also indicate needs for additional specialized measurement.

In addition to the level of detail, training and research needs may also differ with regard to the timeliness and format of measurement. Training information is needed during or at the end of a flight or simulator mission; research measurement can normally wait for a reasonable computer processing turnaround. Training information may require formatting in graphic and pictorial form for student debriefing; research information generally must be numerical for analytical computations.

APPENDIX A

PROTOTYPE MEASUREMENT

PROTOTYPE MEASUREMENT

Prototype measurement is presented in subsequent sections for the following maneuvers:

- Takeoff & Climb
- Pattern, Land or Go-Around
- Instruments -- General
- Instruments -- Example
- Formation
- Intercept
- Air Combat Maneuvers
- Air Refueling
- Ground Attack
- Air Drop
- Air Drop Formation
- Radar Navigation and Bombing

The format used is to present a discussion together with prototype measurement, indicating through a table, the types of information which are considered important to a description of pilot performance. Further development in each of these measurement problem areas will take place, and fuller discussion will be made after expanded analysis permits better treatment. The current materials are presented to briefly summarize important measurement which has resulted from discussions with combat-crew training personnel.

TAKEOFF & CLIMB

All aircraft takeoff and climb to a cruising altitude and configuration. Fixed-wing aircraft perform these maneuvers in basically the same way; however, at a detailed level there are distinct differences between aircraft. Thus, measurement must be tailored to each aircraft, but the general structure of such measurement may be defined so that the essential elements are constant across aircraft. The following sequence is rather basic: Takeoff roll, Rotation, Liftoff, Gear-up, Flaps-up, Climb and Level-Off. The information desired within each of these flight maneuvers may also be expressed in a substantially common manner.

Conditions. To properly interpret measurements made during a particular flight, information on the conditions existing at the time are needed. The gross weight, wind direction and velocity, runway direction and length, temperature, altimeter setting, field elevation, and position of the aircraft in formation, are reference data for the evaluation of performance.

Takeoff roll. The takeoff will be assumed to begin with the application of power. The takeoff roll maneuver will be considered finished at rotation. The objective is to accelerate in a straight line along the centerline, or parallel to the centerline, with wings level. Power and resultant acceleration must be checked; for heavy aircraft and/or short field takeoffs, acceleration checks are formally performed. Time and distance along the runway are checked against airspeed to determine if necessary acceleration performance is lacking in time to safely stop the aircraft. Reject speed is noted in case of an emergency. The formation flight leader must slightly reduce power to allow a margin of thrust control for other members of the flight.

Rotation. Proper rotation is normally necessary to achieve predicted takeoff performance. Rotation will be defined as the activities between the time that the nose gear lifts off the runway until the time that a stable pitch attitude is established. Stabilizer trim is important, bank angle, centerline and heading deviations should be small. Rotation should occur within 1-2 KIAS of the desired rotation speed. The rate of rotation should not be either too large or too small. A specific pitch attitude should be established without overshoot or oscillation.

Liftoff. Liftoff is a discrete event, occurring when vertical velocity is positive. At this time, the airspeed, pitch angle, bank angle, and heading are noteworthy. The vertical velocity a short time after liftoff may also be measured to indicate whether the aircraft is positively airborne, or if there is any tendency to settle back to the runway.

Gear-up. Measurement should be taken from the time that the gear handle is raised until the time that the landing gear are up and locked. The initial speed at which the gear are raised, the change in vertical velocity during the time that the gear are coming up, and pitch, bank, and heading, should be measured.

Flaps-up. Flaps-up measurement is treated in somewhat the same manner as for gear-up, for the tasks are somewhat the same: a configuration change is occurring which presents a perturbation in longitudinal control. A trim change occurs, and pitch, bank, and heading must be controlled. Normally, flaps must not be raised before a specific altitude and airspeed (but before maximum flaps speed), and during the transition to flaps-up, changes in airspeed, vertical velocity, and altitude indicate whether the maneuver is properly performed.

The B-52 presents a special measurement requirement since a specific speed schedule must be maintained as flaps are raised; in addition to airspeed, pitch angle, altitude, vertical velocity, and stabilizer trim are of interest during this period of time.

TAKEOFF & CLIMB*

CONDITIONS:

Gross Wt: ____ Wind: ____/____ Runway: ____/____
Temp.:____ Alt. Set.: ____ Field elev. ____ Form Pos.:____

TAKEOFF ROLL: (TO power until rotation)

Power Set: ____ Centerline Dev.: Min, Max, Av.
Reject Speed: Computed Heading: Min, Max, Av.
Time: ____ Dist: ____ Bank: R Max, L Max

ROTATION: (Nose gear off until pitch att. established)

Rot. Speed: ____________ Stab. Trim: __________
Pitch: Rate:__________ Bank: __________
Final: __________ Centerline Dev.: ____
Overshoot:________ Heading: __________

LIFTOFF: (Pos. Vert. Vel.)

Unstick Speed: ____ Pitch: ____ Bank: ____ Hdg:____
Vert. Vel. After: ____ Sec:____

GEAR-UP: (Handle up until gear-up & locked)

Gear-Up Speed: ____ V.V. Init.: ____ V.V. Final: ____
Pitch: ____ Bank: ____ Hdg: ____

FLAPS UP: (Start up to full up) Note: F106 has no flaps

Trim: ____
Pitch:____ Bank: ____ Hdg: ____
A/S (INIT)____ (FINAL) ____
VV (INIT)____ (FINAL) ____
ALT (INIT)____ (FINAL) ____

B-52 Only	IAS	PITCH	ALT	VV	TRIM
Start	X	X	X	X	X
1st Pos	X	X	X	X	X
2nd Pos	X	X	X	X	X
Full	X	X	X	X	X

CLIMB & LEVEL-OFF: (Depends on Flight Plan)

	PWR	A/S	MACH	HDG	ALT	ALT	PITCH	TRIM
Accelerate	X	X	X	X	X	X	X	X
(#1) Climb A/S	X	X	X	X	X	X	X	X
(#2) Climb MACH	X	X	X	X	X	X	X	X
Level-Off (Alt-10%VV) (to Cruise)	X	X	X	X	X	X	X	X

*Also, mandatory communication & instances where A/C limits are exceeded.

Climb and Level-off. For each aircraft, there are a number of methods for climb-out depending on the flight plan, and desires for economy or performance. It may be desirable to measure climb performance from liftoff, or to start when the aircraft is in a clean configuration. This phase may be divided into the following parts: acceleration, maintain climb airspeed (may be several increases in airspeed during the climb), maintain climb Mach number, and level-off (normally level-off begins at an altitude which is below cruise altitude by 10% of the vertical velocity). Power, airspeed, Mach, heading, initial and final altitude, pitch angle, and trim, are parameters which may be measured during each portion of climbout.

PATTERN, LAND OR GO-AROUND

The return-for-landing maneuvers are also required of all fixed-wing aircraft, and, except for specific details, are tractable by means of a common-measurement approach. The principal differences, of course, occur between heavy and high-performance aircraft.

Conditions. As reference data for the construction of measurement, information is needed with respect to gross weight, wind direction and velocity, runway length and direction, field elevation, temperature, altimeter setting and position in formation. Additionally, information may be needed about visibility and runway conditions.

Initial. While not applicable to the C-141 and B-52, all the other aircraft of the current sample perform a pitchout maneuver over the runway to slow speed and change configuration for a fast and efficient landing. At the initial approach fix, power, airspeed, altitude, heading, and ground position, provide information to determine whether the maneuver is entered properly.

Pitchout. Pitchout measurement would be taken from the time of entering a hard turn until wings are again level. Except for the C-130 (which performs a 45^{o} bank, constant altitudes turn without specific reference to G's and angle of attack), a bank is established which will result in pulling specified G's until a nominal angle of attack is reached; this is maintained until rolling out on the downwind leg. The power, and speeds for use of air brakes, gear, and flaps, are important. As the pitchout probably occurs from formation, passage over the pitchout point, and spacing established, should be measured.

Downwind. On downwind, heading, airspeed, altitude, power and trim should be noted. An additional configuration change may be made. The lateral distance from the runway should be appropriate for a landing, as should be the spacing between elements of the formation.

PATTERN, LAND OR GO-AROUND

CONDITIONS:

Gross Wt: ____ Wind: ____/____ Runway: ____/____ Fld Elev: ____
Form Pos.: ______ Temp: ______ Alt. Set: ______

INITIAL (Not applic. C-141, B-52)

Power: _____ A/S: _____ Alt: _____ Hdg: _____ Ground Pos.: ____/____

PITCHOUT: (Not applic. C-141, B-52) (Pitchout PT. to Wings Level)

Bank: _____ G: (Not C-130) AOA: (Not C-130) A/S: ____ Alt: _____
Power: _____ Air Brakes -- Out Speed____ In Speed____ Gear Speed____
Flaps -- Speed: _____ Amount: _____
Pitchout PT: _____/_____ (Spacing-- #2____#3____#4____)

DOWNWIND

Hdg: _____ A/S: _____ Alt: _____ Power: _____ Trim: _____,_____
Flaps -- Speed: _____ AM'T: _____
RWY Lateral Dist: _____ (Spacing -- #2____ #3____ #4____)

BASE, DOGLEG, FINAL:

ALT.	A/S	HDG	VV	BANK	AOA	POWER	TRIM	FLAPS	C/L	GRAPH:
900	x	x	x	x	x	x	x	x	x	Alt vs Ground
800	x	x	x	x	x	x	x	x	x	Track
:										
200	x	x	x	x	x	x	x	x	x	
100	x	x	x	x	x	x	x	x	x	

LANDING

Threshold:

Alt:_____ A/S:_____ C/L Dev:_____ Hdg: _____ Bank:_____ Drift: _____

Touchdown:

A/S:_____ VV:_____ Hdg:_____ Bank:_____ Pitch:_____ C/L Dev:_____ Dist:_____

Rollout:

Hdg: _____ C/L Dev: _____
A/S: Nose Gear Down:_____ Thrust Rev.:_____ AM'T:_____ Brakes:_____
: Nose Steer: _____ Drag Chute: _____
Stop Dist: _____

GO-AROUND

Power: _____ Speed Brakes in at Max Power? _____ Flaps: Speed_____,
AM'T: _____ Gear-UP Speed: _____
Pitch: INIT: _____ GO-AROUND: _____ MAX: _____ BANK: _____
Alt: INIT: _____ Min.: _____ V.V.+: _____ Min After V.V.+: _____

---

*Also, Mandatory Communication.

Base, Dogleg, and Final. The objective of base, dogleg, and final legs, is to establish an approach path to the desired point on the runway. Airspeed, heading, vertical velocity, bank angle, angle of attack, power, trim, flaps, and deviation from the runway centerline are important parameters, but seem to be most meaningful when expressed in relation to altitude. Thus, these parameters may conceivably be best presented in conjunction with a plot of ground track.

Landing. While a great deal of information may be collected which is relevant to landing performance, it is commonly stated that the important information is the condition of the aircraft over the threshold, at touchdown, and at stopping (for short-field landings). The basic parameters of importance are altitude, airspeed, centerline deviation, heading, bank angle, cross-runway drift, pitch angle, vertical velocity and distance down the runway. During landing rollout, the use of various types of braking is of interest where more detailed description of performance is desired.

Go-Around. The objective of a go-around, or low-approach, is to safely regain climbing speed with a minimum loss in altitude. Thus, the use of power, flaps, speed brakes and gear is important. Control of pitch is critical for optimal go-around performance; note should be made of the average pitch in comparison to the optimum value, and the maximum pitch angle in comparison with the never-exceed value. The loss in altitude from the initial value at the lowest point, at the point where positive vertical velocity is attained, and the minimum therefore, should be noted. Bank control throughout the maneuver is also important for measurement.

INSTRUMENTS, GENERAL

Instrument flying involves precise aircraft control superimposed by the requirement to stay within airspace boundaries defined by the air traffic control environment. For measurement purposes, it is possible to discuss separately, basic aircraft control and navigation performance with respect to the air traffic control environment.

Basic aircraft control. The pilot must be able to control the aircraft in pitch, roll, yaw and thrust/drag in order to achieve desired headings, turn rates, rates of climb or descent, target altitudes and airspeeds. The ability of the pilot to perform this control should be measured. This measurement must be sufficient to allow interpretation of control actions in the opinion of operational instructors, which obviates the need for more detailed control stick and pedal pressure or movement data. Various treatments of the indicated parameters require definition.

One treatment would be to document for each required maneuver, the average value, the variability, and/or the peak deviations of the parameters. Maneuver start and stop logic

INSTRUMENTS -- GENERAL

BASIC AIRCRAFT CONTROL

Pitch: ____ Roll: ____ Thrust: ____ Heading: ____

Speed: ____ Mach: ____ Altitude: ____ Vertical Velocity: ____

Angle of Attack: ____ G's: ____

NAVIGATION

Aircraft Position, Altitude and Speed Relative to Clearance and Published Procedures:

- Radio Frequency and Course Datum
- VOR/TACAN Course Error
- Cross Track Error
- Vertical Profile Error (Constant altitude, rate of descent or glide path)
- Speed Profile Error
- Time Errors: ETA Accuracy, Time to Execute or Capture
- Intercept of Arcs from Radials
- Maintaining Arcs
- Intercept Radials from Arcs
- Holding Pattern: Entry and Maintenance

would be required to initiate the measurement. Additionally, if a particular maneuver is divided into logical sub-maneuvers, additional logic may be needed. For example, a constant altitude turn might be broken-down into turn entry, sustained turn, and recovery sub-maneuvers, each of which might require slightly different measurement emphasis.

Another data treatment would include comparing each of the sensitive parameters against a standard for the maneuver, and outputting an error score. Current operational practice employs the tolerance band technique to reduce the amount of data that has to be handled, and to "filter" non-meaningful data. In a similar fashion, it is assumed that tolerance bands will be constructed where appropriate and excursions beyond the tolerance band will be scored. For example, during straight and level flight a pilot might be required to hold wings level $\pm 5^{\circ}$, altitude $\pm$ 100 feet, heading $\pm 5^{\circ}$, and airspeed $\pm$ 5 knots. Only excursions beyond these values would be scored by this data treatment. The tolerances can change as a function of the particular aircraft, maneuver, and the skill level of the pilot. The tolerance band approach assumes that somewhere in the measurement system exists (1) memory or knowledge of the tolerances, (2) computational capability to compare the actual vs. desired, and (3) the medium for outputting the results.

Navigation. Superimposed on the requirement of the pilot to maintain precise aircraft control is the requirement to move the aircraft through the air traffic control environment (civil or tactical) in accordance with the airspace boundaries expressed by or implied by his clearance. As an aid to navigation, various radio and radar facilities provide horizontal and (sometimes) vertical route definition. In addition to flying the aircraft precisely (basic aircraft control), the pilot must maneuver through the route; his performance with respect to that route and changes in that route (as they emerge) are important measurement candidates.

For measurement purposes, there is little difference between enroute, terminal area, or instrument approach profiles. In a non-radar environment a radio facility must be tuned and precise procedures flown. The radio frequency which is tuned along with the desired course should be measured. The aircraft position (and altitude) relative to the clearance should be measured; candidates include VOR/TACAN course error, cross track error (preferably in nautical miles), airspeed profile errors, time errors (ETA accuracies), ground tracks when intercepting arcs from radials, maintaining arcs, transitioning from arcs to radials, holding pattern entry and maintenance, and vertical navigation climb/descent profiles (including penetrations and glide path holding).

Just as with basic aircraft control, the measurement of navigation performance tends to require error criteria in the form of tolerance bands as well as additional data treatment.

Measurement sets should be sensitive to excessive maneuvering by the pilot; excessive maneuvering would be characterized by inappropriate overshoots or undershoots when capturing courses, arcs, glide paths or altitudes. Measurement should be equally sensitive to insufficient maneuvering which might be described as allowing a course error for too long, insufficient intercept angles, or excessive use of airspace.

Comment. Although the criteria for instrument flight performance are relatively clear, it is apparent that a sophisticated measurement system will be required to obtain and transform relevant performance data into a form that is manageable and useful. The system must know the flight plan and the clearance, the radio frequencies and courses required, the altitude profiles required and where the aircraft is at all times in order to score against this profile. Precisely where (airborne or ground) this kind of intelligence is placed into the measurement system has yet to be determined.

A more concrete example of the instrument flying performance measurement requirement is addressed in the next section.

INSTRUMENTS--EXAMPLE

Exemplary measurement is shown for the Vulture One instrument departure from Luke AFB. For measurement purposes, the departure is divided into five segments.

Take-off. This first segment would require measurement identical to take-off (treated elsewhere in this report).

Climb established to 4n.m. DME fix. Precise definition of this second segment would depend upon the particular aircraft for which the measurement was intended. The climb and flap schedule required of the B-52, for example, might overlap this segment. Suffice it to say that generally, while aircraft "clean-up" and acceleration are underway, the following measurement is suggested by the problem:

The TACAN should be tuned to Channel 77, and the outbound 294° radial should be set-in. Minimum, maximum and average airspeed will show acceleration performance. For the A-7 aircraft, the maximum airspeed will be of diagnostic value. If the pilot accelerates to the normal climb speed, he will be unable to complete the next segment within the airspace limits. Maximum altitude is monitored to insure that the pilot does not exceed the 4,000 foot restriction. Minimum, maximum and average vertical velocity should indicate the smoothness of his acceleration and climb. The procedure requires flying runway heading. The average deviation from the runway heading and the peak deviations (left and right) are suggested. If heading departs from the runway heading by more than 5°, the amount of time out of the tolerance band should indicate severity of this deviation.

Monitoring roll attitude maximum left and right deviations in addition to time outside of 10^{o} should be of diagnostic value.

4 n.m. DME fix to LUF TACAN. The third measurement segment is a climbing 270^{o} turn (approximately) directly to the station with an altitude limit of 4,000 feet and an airspace restriction not to exceed the 8nm DME arc. Since turn radius is a function of bank and airspeed, the A-7 pilot will have difficulty staying within this airspace if his airspeed is too high. Similarly, his vertical velocity will be sufficiently high that he will quickly achieve 4,000 feet. The segment suggests the following measurement:

The minimum, maximum and average pitch attitude will show the boundaries pitch performance. Roll attitude maximum value will indicate any extreme maneuvering. Airspeed performance can be a problem in a higher performance aircraft; the minimum, maximum and average values are recommended. Airspace restrictions are defined by altitude and DME range. In addition to the minimum, maximum and average value of altitude throughout the segment, if altitude exceeds 4,000 feet, the amount of time the pilot was above 4,000 feet should be scored to determine if the excursion or excursions were momentary or substantial. The maximum DME range achieved will define the horizontal airspeed used. If DME range exceeds 8 n.m., then the time that the aircraft was beyond 8 n.m., the airspeed, the minimum maximum and average roll attitude, and the minimum, maximum and average thrust should provide sufficient diagnostic information.

LUF TACAN. The fourth segment is station passage. The following measures are recommended: (1) Time over the station, (2) Altitude, (3) Heading, (4) Airspeed, (5) Roll attitude, (6) Thrust and (7) DME range. The DME range can be used together with the altitude and the known altitude of the facility to compute the circular error when crossing or passing abeam the station. DME range would probably be a candidate for the determination of station passage; when it stops counting down and starts counting up, station passage has occurred. Whereas, at low altitude station passage happens quickly and in a clean fashion, it is more difficult at 30,000 feet to determine (in real time) exactly when the aircraft was over the station.

LUF to Vulture. It is assumed that the aircraft would start a climb profile upon crossing the TACAN, if the normal climb profile would not have been in progress prior to the crossing. In this final segment, the flight problem is simply to climb out while tracking the 294^{o} radial, insuring that you will cross Vulture at or above the indicated altitudes. Measurement of the minimum, maximum and average values of the following are suggested: (1) Airspeed, (2) Heading, (3) Cross-track deviation computed in nautical miles, (4) Vertical velocity, and (5) Pitch attitude. Roll attitude measurement includes the maximum left bank, maximum right bank and the average. Should cross-track deviation exceed 4 n.m. (normal airway width), the amount of time the

INSTRUMENTS: EXAMPLE

(VULTURE ONE DEPARTURE--LUKE AFB)

TAKE-OFF: See Take-Off Measurement to Flaps-Up.

FROM CLIMB ESTABLISHED TO 4n.m. DME FIX

TACAN TUNED: CH 77, 294° Radial Set-In.

Airspeed: (Min, Max, Avg)

Altitude: (Max)

V/V: (Min, Max, Avg)

Heading: (Max L, Max R, Avg of Rnway Heading — If Hdg >±5°, Time Out

Roll: (Max L, Max R, Avg) — If Roll >±10°, Time Out

4n.m. DME FIX TO LUF TACAN

Airspeed: (Min, Max, Avg)

Altitude: (Min, Max, Avg) — If Altitude >K, Time Out

DME Range: (Max) — If DME Range >8nm; Time Out: ______

Airspeed: ______

Roll: (Min, Max, Avg)

Thrust: (Min, Max, Avg)

Pitch: (Min, Max, Avg)

Roll: (Max)

LUF TACAN

Time: ______ DME Range ______

Altitude: ______

Heading: ______

A/S: ______

Roll: ______

Thrust: ______

LUF TO VULTURE

Airspeed: (Min, Max, Avg) (Assume Start Climb Profile)

Heading: (Min, Max, Avg)

Roll: (Max L, Max R, Avg)

Cross Track Deviation: (Min, Max, Avg) If X Track Exceeds 4n.m

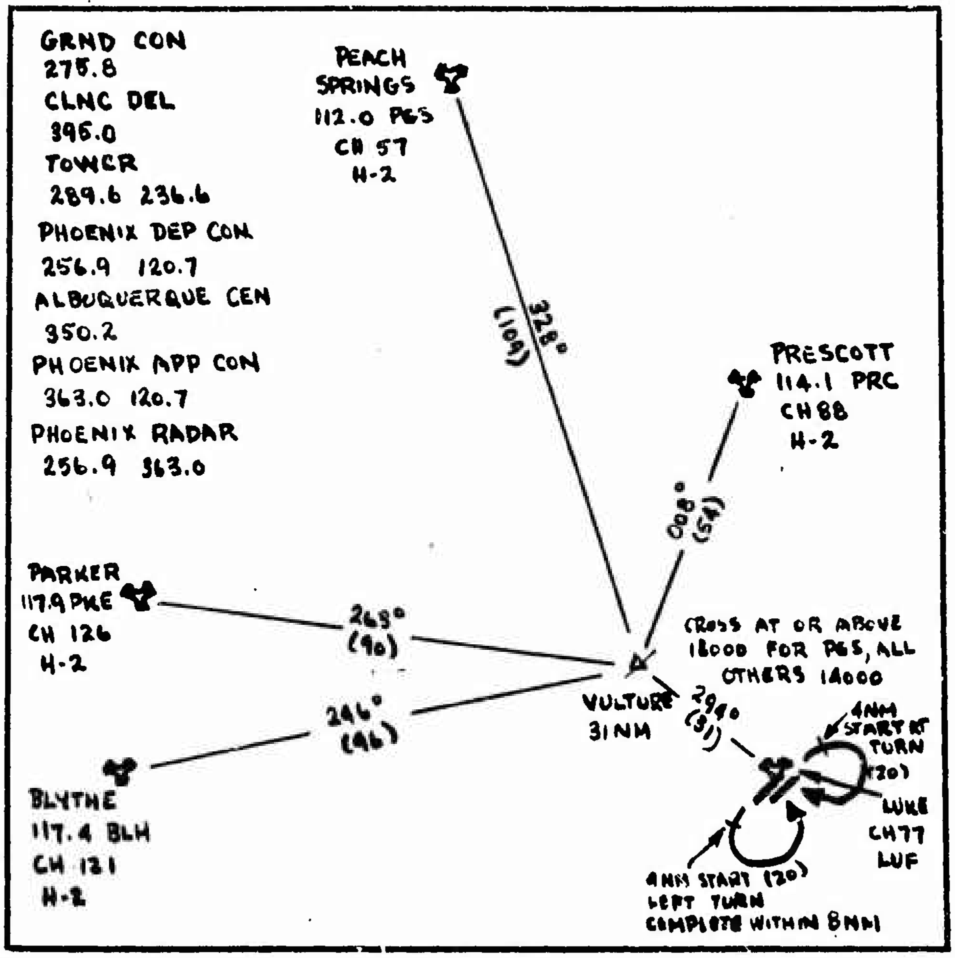
V/V: (Min/Max/Avg) — Time Out: ______

Pitch: (Min/Max/Avg) — DME Dist Out: ___ In: ___

Altitude: (At or Above MCA at Vulture)

VULTURE ONE DEPARTURE

LUKE AFB



DEPARTURE ROUTE DESCRIPTION

Climb Rwy heading to 4 NM DME Fix. Turn right/left proceed direct to "LUF" TACAN complete left turn within 8 NM DME. Cross "LUF" TACAN at 4000' via "LUF" TACAN 294 radial to VULTURE INTXN ("LUF" 294 radial 31 NM DME Fix). Cross VULTURE INTXN ("PGS" Transition 18,000'; all others 14,000') then via (Transition) or (Assigned route).

<u>BLYTHE TRANSITION:</u> Via BLYTHE 066 radial to BLYTHE VORTAC.
<u>PEACH SPRINGS TRANSITION:</u> Via PEACH SPRINGS 148 radial to PEACH SPRINGS VORTAC.
<u>PRESCOTT TRANSITION:</u> Via PRESCOTT 188 radial to PRESCOTT VORTAC.
<u>PARKER TRANSITION:</u> Via PARKER 083 radial to PARKER VORTAC.

aircraft spends outside of 4 n.m. in addition to some indication of where the error occurred is recommended. A tally of the DME distance when the departure occurred as well as DME distance when the aircraft returned inside the 4 mile boundary is suggested. Finally, the altitude of the aircraft when crossing Vulture is needed to insure proper climb performance.

FORMATION

Much of military flying, especially that in fighter aircraft, is done in formation. Consequently, measurement of formation flight performance must be done in combination with measures of the specific maneuvers done while in formation. Therefore, while the following discussion will relate to formation measurement, it should be understood that formation is a means to an end, and that other mission-critical measurement should also exist.

There are a number of types of formation, each designed for a specific purpose. Among the various types of formation are: fingertip, echelon, route, trail, and fluid (patrol and fighting wing). For current purposes, these types of formation are simply divided into close formation and trail formation, together with the maneuvers for initially joining the formation. A number of formation types are combined into close formation, but it is believed that common measurement is possible, as long as the criteria for holding specific range, azimuth, elevation, and attitude relationships is varied for the requirements of each unique application. It should also be noted that Air Drop Formation is discussed elsewhere, as this appears to pose different requirements for measurement.

A distinction is necessary between formation measurement for the flight leader and for the wingman. At times it may be necessary for the flight leader to perform violent maneuvers and for the wingman to maintain his relative position; however, it frequently will be to the best interests of the mission to be performed if the flight leader is restrained to rather gentle slow maneuvers, allowing sufficient power differential for the wingman to maneuver and hold position.

Therefore, it may be necessary to measure such items as power setting and airspeed for the flight leader during join-up, and closing rate and the time to join for the wingman. During close formation, turn rates, vertical G, and throttle rates must be restrained for the flight leader, while the wingman must maintain constant relationships for range, bearing, and altitude, staying in trim, with smooth use of controls.

Trail formation requires maintaining a specific spacing in terms of separating range and altitude. Normally, a specific ground track may be required or desired. Here the formation may be held without visual contact; the primary guidance is provided by airborne radar equipment. For all types of formation, certain radio calls may be important, and knowledge and use of hand signals necessary.

FORMATION*

JOIN-UP

Lead: Power: ____________ A/S: ____________

Joining Element: Closing Rate: Max, Min, Av.

Time to Join-Up: ________________

CLOSE FORMATION

Lead: Turn Rate:

Vert. G.:

Throttle Rate:

Wingman: Trim: _____ Stick Activity: Pitch: _____ Roll: _____

Spacing	Range	Brng	Δ Alt.
#1 - #2			
#1 - #3			
#3 - #4			

TRAIL

Ground Track Dev: ________________

Spacing: Range: __________ Alt: __________

*In conjunction with other normal flight maneuvers; also, consider radio calls, use of hand signals.

Measurement of formation performance involves relating information from a number of ships in the formation. These measurements appear to be technically feasible; however, current measurement is performed by subjective observations which may be quite satisfactory depending on the magnitude and level of detail measurement is to achieve. Subjective measurement would be performed by the flight leader who apparently is able to quickly spot deviations from proper performance; on the other hand, he may not always be in a position to observe performance, such as when in trail formation.

INTERCEPT

Intercept measurement is based primarily on F-106 because it is a pilot task in that vehicle. The intercept problem is essentially the same for the F-4: however, there is a radar observer to perform the scope work and differences in the equipment and capability suggest that slightly different strategies might be employed. The measurement requirements have been specified on a common basis where possible. Of the six measurement segments, the measurement of re-attack would take a different complexion in the F-4 than what is suggested herein.

Initial conditions. Evaluation of the pilot's performance depends much on the initial conditions of the intercept exercise. These conditions require documentation. The target track, altitude, mach, countermeasures and evasive actions (if any) should be logged. The type of attack planned for the interceptor should be documented as well as the altitude, mach, initial closing velocities (V_c) and track crossing angles (TCA). The performance expectation of the pilot to actually achieve success will depend on his background experience and the relative difficulty of the "set-up". One would expect different performance data to emerge in the remaining segments as a function of these initial conditions.

Search. Two things are critical in search, (1) scope adjustment and (2) looking where the target is. Three parameters describe the adjustment of the scope, IF gain, Video gain and Erase gain or intensity. These parameters must be set for optimum target detection under the prevailing conditions; no one set or combination of gains is ideal. Having set-up the scope, the next problem is looking where the target is in elevation (radar look angle). The measure suggested here should be the difference between the actual angle of the target and the interceptor radar antenna angle. Target detection range should be measured. While radar search is ongoing, the pilot must fly the aircraft. Aircraft control heading, altitude and mach (minimum, maximum and average) are suggested to monitor his performance. If the target is not detected until turn-in, search may continue into, or even through the next segment.

INTERCEPT

INITIAL CONDITIONS

Target: Track:____ Altitude:____ Mach:____ ECM:____ CHAFF:____

Interceptor: Type of Attack: (Snap; Co-altitude; Data Link; Close Control; MCC)

Altitude:____ Mach:____ V_C:____ TCA:____

SEARCH:

Scope Adjust: IF Gain:____ Video Gain:____ Erase Gain:____

Radar Look Angle:____ Target Detection Range:____

Radio Call : (Judy)

Aircraft Control: (See Turn-in)

TURN-IN:

Range:____ Aspect Angle:____

Lockon Sequence: Elevation Spotlight Time on Target:_____

Azimuth Spotlight Time-on-Target: ______

Range Gate Pre-position: ______________

Lockon Range: ________________________

Aircraft control (min, max and avg): Heading:_____ Altitude:____

System Mode and armament selection.

ATTACK:

Aircraft control (min, max, and avg): Pitch:____ Roll:____

Mach: ___ Angle of Attack:____ G's;____

Intercept Geometry (min, max, and avg): Bearing:____

Δ-Altitude:____ V_C: ____

Steering error:____ TCA:____

At Missile Firing: All above + Probability of Success:____

For Snap-up attack: Aircraft control and intercept geometry data at conclusion of pitch-up.

RE-ATTACK:

Turn point range:____ Δ-Altitude:____ TCA:____ Roll: (Min,Max,Avg)

At rollout, repeat search through attack measurement, as appropriate.

SPECIAL WEAPON ESCAPE:

Time from Release to Max G: ____

Minimum, maximum and average: Pitch:____ Roll:____ Mach:____ G's:____

Turn-in. The aircraft is usually vectored into an attack initial position, usually described as a turn-in point. Further definition of the intercept set-up requires knowledge of the turn-in range and the target aspect angle at turn-in. Although it can happen at any time after target detection, the target lockon sequence usually follows turn-in. The purpose of lock-on is to designate the target to the fire control system in terms of elevation, azimuth and range. Time-on-target type of measurement is recommended for each of these parameters. When lock is achieved, the range should be documented. While lock-on is progressing, the pilot must continue to fly the aircraft with reasonable accuracy. Measurement of heading, altitude, pitch, roll, and Mach (min, max, and avg) are suggested. Additionally, system mode and armament switches must be placed in proper positions for attack.

Attack. Monitoring of aircraft parameters during attack is suggested; however, these data must be properly weighed because the fundamental requirement is to perform a successful attack. Essentially, the measures suggested would tend to disclose any unsafe practices such as unusually high g's or extreme angles-of-attack. Intercept geometry prototype measurement is based on either a frontal (front quarter) or stern attack. A conversion from the beam to stern, or from the beam to front quarter would require additional consideration. Minimum, maximum and average values for target bearing, altitude difference, closing velocity, steering error and track crossing angles are suggested. When the missile is fired, all of the indicated parameter values should be measured in addition to missile parameters in order to compute the probability of success. For the snap-up attack, the parameter values (aircraft control and intercept geometry) should be measured at the conclusion of the pitch-up maneuver.

Re-attack. The turn point range, altitude difference, track crossing angle, and roll attitude parameters are suggested for re-attack. At rollout, search, turn-in, and attack measurement is suggested, contingent on the intercept situation that develops.

Special weapon escape. The time from the release point until maximum g's are obtained together with pitch, roll, mach and g measurement is suggested. There are several ways to perform the escape maneuver; each method is situation dependent. Situational dependencies may require slight alterations in measurement. Operational comment suggests that pilots usually don't respond fast enough or pull sufficient g's, so the principal diagnostic measures are included.

AIR COMBAT MANEUVERS

Air combat maneuvers will require further definition and study before tractable to detailed performance measurement. However, prototype performance measurement is indicated which, it is believed, is consistent with much of current training. It is

AIR COMBAT MANEUVER

(SET-UPS)

INITIAL POS.:

Pos. of Attacker: Range: _____ AZ: _____ Elev: _____

Attacker: Alt: _____ A/S: _____ Fuel: _____ Energy: _____

Defender: Alt: _____ A/S: _____ Fuel: _____ Energy: _____

MANEUVER: (Hard Turn, Hi- or Lo-Spd Yo-Yo, Scissors, Barrel-Roll, ...)

As Required by Maneuver (time sampled): Alt, A/S, Bank

Picth, Yaw, AOA, G, VV, Hdg, Power (A/B).

Plot: A/S vs G vs AOA

FINAL POS.:

Pos. of Attacker: Range: _______ AZ: _______ Elev: _______

Attacker: Alt: _____ A/S: _____ Fuel: _____ Energy: _____

Defender: Alt: _____ A/S: _____ Fuel: _____ Energy: _____

DART FIRING

PASS	TIME	#HITS	A/S	INIT/FINAL RANGE	INIT/FINAL AZ	INIT/FINAL ELEV
1	x	x	x	x/x	x/x	x/x
2	x	x	x	x/x	x/x	x/x
:						
6	x	x	x	x/x	x/x	x/x

believed that two situations lend themselves to measurement: air combat set-ups, and dart firing. Other situations, not currently clearly defined, may also permit measurement development.

Air combat set-ups involve placing attacking and defending aircraft in fixed initial positions, then freeing them to perform a maneuver, and subsequently judging from the final position whether the maneuvers were properly performed and whether proper advantage of the tactical situation was taken. In this approach, air combat is treated as a chess game, taken a move at a time, with the alternatives and pros and cons discussed at each point. Thus, measurement can be directed to description of the maneuvers performed (e.g., hard turn, hi-lo-speed yo-yo, scissors, barrel roll, etc.), and to determining whether a given student was able to improve his situation. Improvement of position can be defined in terms of closing on the stern of the opponent and/or gaining energy with respect to the opponent. Energy can be measured in terms of speed and/or altitude gains.

The prototype measurement for dart firing assumes a butterfly pattern or the equivalent. A pass is made over the target, a time hack is taken crossing the dart, the pilot must circle back to make an intercept to put a hole within the target in a given amount of time. Thus, the time and hits on each pass is measured; additionally the range, azimuth, and elevation at the beginning and end of firing describe the firing position. Fouls are called for low airspeed and for firing within a minimum firing range.

AIR REFUELING

The discussion of air refueling which follows is tailored to the requirements of the B-52, for this task is most difficult for the B-52; however, the measurement indicated can be reduced and adapted for the requirements of other applicable aircraft.

It is assumed that the refueling B-52 will be higher than the tanker and that a controlled descent to rendezvous must be accomplished. At approximately 10 ft. below and 50 ft. behind the tanker, the refueling aircraft should stabilize and hold distance at the pre-contact position, then slowly close until a refueling contact is made. A stripe down the belly of the tanker is used for lateral control. A pair of receiver director lights (colored panels with a green stripe, green and red colors, D and U, and F and A) for Up/Down and Fore/Aft movements of the boom. The pilot also uses the fuselage, wings, and engine nacelles of the tanker as an attitude director. The lights on the Receiver Director Lights indicate need for pitch and power changes (in the buddy system, the co-pilot may control power); the tanker outline in the windscreen and the centerline down the middle of the tanker fuselage provides a source of information for lateral control. The Receiver Director Lights are all green when in the middle of the zone of boom movement; the lights are all red when loss of contact is eminent.

AIR REFUELING

DESCENT*

	% Time in Tolerance			
	Tol. A	Tol. B	Tol. C	Outside Tol.
V.V.	x	x	x	x
A/S	x	x	x	x

RENDEZVOUS*

	Distance		
	2NM	1NM	½NM
ALT	x	x	x
A/S	x	x	x

PRE-CONTACT**

Av. Range: ________ Variability: ________

Av. Δ Alt: ________ Variability: ________

Pitch Activity: _____ Roll Activity: _____ __ Throttle: _____

Air Brack Pos: _____ Stab. Trim: ________

CONTACT**

Contact	Time		% Time	Nr. Colors		C/L	Fuel	Conditions at Disconnect		
	Start	Stop	All Green	U/D	F/A	Dev	Flow	U/D	F/A	C/L
1	x	x	x	x	x	x	x/x/x	x	x	x
2	x	x	x	x	x	x	x/x/x	x	x	x
3	x	x	x	x	x	x	x/x/x	x	x	x
4	x	x	x	x	x	x	x/x/x	x	x	x
5	x	x	x	x	x	x	x/x/x	x	x	x
6	x	x	x	x	x	x	x/x/x	x	x	x

*Appropriate only to B-52

**Video Recording useful

It is often customary for three scoring bands to be established: Highly Qualified, Qualified, and Conditionally Qualified. Performance outside of these tolerance bands would be scored as Unqualified. These conventions are reflected in the prototype measurement for Air Refueling.

Descent. In descending to tanker altitude, the pilot is coordinating with the navigator; vertical velocity and airspeed must be carefully controlled.

Rendezvous. Rendezvous with the tanker is largely a navigator's job, but the pilot is responsible for maintaining altitude and slowing the aircraft according to a distance/airspeed schedule.

Pre-contact. At the pre-contact position, the pilot must hold position and attitude using smooth control actions. Air brake position and stabilizer trim are important. The primary consideration is the amount of variability in range and altitude, and the amount of pitch, roll, and throttle control activity used.

Contact. With the B-52, the pilots are given between 4 and 6 attempts to make a 5-minute contact. A 5-minute contact must be made within 30-minutes after the initial contact. Therefore, the time at which each contact is started, and the time of each disconnect, will indicate qualification. Otherwise, it is of interest to know the stability of control during each contact period; this can be measured in terms of the number of times the Receiver Director Lights change color. Lateral control can be measured in terms of deviation from the centerline stripe on the tanker. Throttle control can be measured in terms of fuel flow. The conditions at disconnect may also aid in defining the proficiency exhibited; these conditions may be described by the lights and centerline deviation at disconnect.

GROUND ATTACK

During training, ground attack is divided into ground attack, ground attack night, ground attack tactical; for measurement purposes these have been judged to present common requirements. Ground Attack Radar is discussed in combination with radar navigation and bombing. Also, a number of ground attack events are trained, e.g., strafe, rockets, dive bomb; again, the measurement requirements are similar, but with different emphasis on specific parameters.

The conditions at the time of weapons delivery should be known in order to properly interpret and diagnose measurement. Among the more important conditions are gross weight, wind direction and velocity and temperature.

The ground attack pattern can be divided into the following parts: downwind/base, turn to final, final, and recovery. The final portion of the pattern (the weapons delivery) is the most

important, of course, but conditions during the other portions of the pattern are considered to be quite important by instructor pilots.

Downwind. Normally a flight of four aircraft will be in the range pattern. The separation between aircraft must be maintained for proper spacing over the target; altitude (AGL) and airspeed should be noted. A number of switches must be set-up for proper weapons firing; other switchology factors must be attended to, such a sight brightness. It will normally be assumed that switches were properly set if weapons are released as expected.

Baseleg. During baseleg, position, altitude and airspeed are again important -- even more important for dive bombing. A radio call to the range is required at this time.

Turn to final. A power change is made to initiate descent and rollout in alignment with the target (or offset aim point).

Final. During a diving pass, initially dive angle should be steeper and the sight slightly below the target, with each of these drifting to the proper values at the time of weapons release. Control of parameter drift is therefore important, but it is generally believed that training information can be derived simply from the conditions which exist at pickle (weapon release). At release, the weapon begins ballistic flight determined by the conditions at release and the effects of wind. Error analyses have been performed to determine the factors and the effect of each; these are (assuming the target is properly aligned with the sight): dive angle, airspeed, bank angle, sideslip, acceleration (G), release altitude and slant range. Given the sight picture at release, an instructor can determine necessary changes in pilot performance from the error analysis items; for strafing, this information would be needed at start and stop of firing. Of course, for weapons delivery on a target range, range personnel will radio a score for each pass in terms of clock code and range for bombs, and number of hits for strafing.

With specialized avionics, such as a Heads-Up Display (HUD) and tactical computing equipment, the pilot is displayed an aiming symbol, a bomb fall line, and a flight path marker. His task is to fly the display symbols to the target, the bomb will be delivered when proper conditions are met. Consequently, measurement of performance using the HUD data would be appropriate.

Recovery. The aircraft must not descent below a minimum altitude, and must initiate a recovery which will avoid fragmentation and terrain. During recovery, a specific Angle of Attack (AOA) and G's are desired. At the crosswind turn, a specific pitch angle should have been attained.

GROUND ATTACK

CONDITIONS:

Gross Wt.: _____ Wind: ____/____ Temp.: _____

DOWNWIND/BASE:

Spacing: #1 - #2____ #2 - #3____ #3 - #4____

Alt.: ____ A/S: ____

TURN TO FINAL:

Alt.: ____ A/S: ____ VV: ____ Pitch: ____ Power: ____

FINAL: (Either, at WPN Release, or, both Start and Stop Firing)

Tgt Align: ____ Dive Angle: ____ A/S: ____ Bank: ____

Slip: ____ G: ____ Rel. Alt: ____ Slant Range: ____

Pos. Tgt on Sight: ____/____

At HUD: Aim: ____ Bomb Fall: ____ Flight Path: ____ Tracking: ____

Bomb Score/Hits: ____/____

RECOVERY:

Min. Alt. ____ Pull-Up G: ____ AOA: ____

Pitch Angle at Turn: ____

AIR DROP

The present discussion of measurement of air drop maneuvers is based on current procedures used in the Tactical Air Command, C-130E squadrons. An expanded discussion of air drop maneuvers for the C-141 appears in Volume IV. Air drop is a coordinated activity between the full crew compliment. Although flying the aircraft to the drop zone, and the drop zone maneuvers are largely navigational in nature, there is an interaction between the navigator's skill and the pilot's skill to fly precise headings, airspeeds, altitudes and tracks. Various enroute procedures can be employed to get to the drop zone; however, the measurement requirements are based on the drop portion of the mission, starting with the turn onto the Initial Position (IP). Five measurement segments are suggested for single ship air drop.

Initial position. An initial position is selected about 10 miles from the drop zone (if possible), usually aligned with the drop zone axis. There is insufficient time or distance to make much of a time correction between the IP and the DZ; the IP, therefore, must be hit with position and time accuracy. The IP altitude, airspeed, position accuracy and time should be measured.

IP to slowdown point. Generally, between the IP and the DZ, a geographic reference point is assigned as the slowdown point. Accurate course, altitude and airspeed must be flown while the crew readies for the drop and completes required checklists. Minimum, maximum and average values for the following reflect pilot performance: (1) Altitude, (2) Heading, (3) Cross-track deviation, and (4) Airspeed. Additionally, permission to enter the drop zone must be obtained by radio; however, this is usually a copilot function.

Slowdown point. At a geographic reference point, the aircraft is slowed from enroute speed (usually 230-250 KIAS) to the drop airspeed which can vary from 115 to 130 KIAS as a function of the equipment or personnel to be dropped. Simultaneously, the drop altitude must be achieved and stabilized. In slowing from enroute speed to the drop speed, any wind drift correction will approximately double. If an altitude change is required, the winds may change further; at low altitude the turbulence and accuracy requirements demand the utmost in flying skill. Precise adherence to the sequence and procedures are required because the drop is normally conducted in formation (see air drop formation) which demands that each aircraft do precisely the same thing.

At slowdown, throttles are moved smartly, but smoothly to flight idle. If a climb is required to the drop altitude, 5° of pitch attitude is used. If a descent is required, a 1,000 fpm rate of descent (bleeding airspeed to 140 KIAS) is used until the drop altitude is achieved. Adherence to the flap schedule by every aircraft assures uniform deceleration and spacing between aircraft in formation drops. Measurement of thrust,

AIR DROP

INITIAL POSN (IP)

Time: ______ Altitude: ______ Airspeed: ______
Position Accuracy: ______

IP TO SLOWDONW POINT:

Altitude: ______ Heading: (Min, Max, Avg)
Cross Track Dev.: (Min, Max, Avg) Airspeed: ______

SLOWDOWN POINT: (Geographic Posn Until Stabilized at Drop Airspeed and Altitude)

Thrust: (Cruise Pwr to Flt Idle)
Airspeed: ______
Pitch: ______
Roll: ______
Altitude: ______
X-Track Dev.: ______
Heading: ______

Flap Schedule

A/S	Position
220	10%
210	20%
200	30%
190	40%
180	50%

	Pitch	V/V	A/S	
Climb	5^{0}	-		To Altitude
Descent		-1000	140	To Altitude

Drop A/S

Personnel	Experienced Personnel	Equipment
115	125	130

DROP: (From Stabil. at Drop A/S & Alt to Red Light)

Thrust: ______ Pitch: ______ Altitude: ______ X Track Dev.: ______
Air Speed: ______ Roll: ______ Heading: ______
Time of Arrival: ______

Posn at Green Light

Relative to CARP: ______
+Interphone Record: ______
A/C Posn at Rel Light:
Drop Circular Error : (YARDS) (Distance))
Drop Directional Error: (Clock Code)) From
Drop Zone Winds: (Dir/Vel)) Target
Doppler Winds at Altitude: (Dir/Vel)

ESCAPE: (Red Light to Enroute A/S & Altitude) (Also, relative to Flight Plan as Briefed)

Airspeed: ______ Altitude: ______ Pitch: ______ Roll: ______
Hdg: ______ Time from Red Light to 90^{0} ITI: ______

airspeed, pitch, roll, altitude, cross-track deviation, heading and flap position are suggested by the maneuver.

Drop. This segment starts when the aircraft is stabilized on the drop airspeed and altitude, and continues until the DZ is passed ("Red Light"). Extensive calculation of the ballistic fall, the parachute fall, and the effects of winds enter into a computed air release point (CARP). The CARP is calculated on the ground by the navigator based on anticipated winds. Between the IP and the DZ, the navigator updates the CARP based on latest wind information from the ground and the airborne doppler. The time of arrival (TOA) at the drop zone must be within 120 seconds of the schedule according to current criteria.

Minimun, maximum and average values of the following parameters are suggested for measurement: (1) Thrust, (2) Pitch, (3) Roll, (4) Altitude, (5) Airspeed, (6) Heading, and (7) Cross-track deviation. Aerial delivery scoring suggests the following measurement: (1) aircraft time of arrival, (2) aircraft position relative to the CARP at "Green Light" (the release point), (3) drop circular and directional error, (4) drop zone winds, (5) doppler winds at altitude and (6) aircraft position at "Red Light". Because the drop involves extensive crew coordination, an interphone record appears necessary to complete the measurement set.

Escape. The escape maneuver can vary as the tactical situation dictates. Measurement of airspeed, altitude, pitch, roll, heading and thrust settings is suggested relative to the briefed flight plan from the onset of "Red Light" until the enroute altitude and airspeed are achieved.

AIR DROP FORMATION

The VFR In-trail formation for the C-130E aircraft is slightly different than fighter aircraft and earlier airdrop formations. Three aircraft form an element. The number two aircraft flies 2,000-feet behind the leader and slightly to the right (about 60-feet) to stay out of lead's wingtip vortex. The number three aircraft flies 4,000-feet behind lead and slightly left. At enroute speeds the aircraft are about 5-seconds apart which provides a maneuverable formation. Over the drop zone, the formation becomes referenced to the DZ axis and aircraft longitudinal spacing remains the same. Due to a decrease in airspeed, about 10-seconds separates each aircraft. Once the formation slows down, each aircraft is required to maintain his position on the leader relative to the DZ axis. Any cross-wind component thus changes the sight picture from the number 2 or 3 aircraft from what it was during the enroute formation. It is obvious, also, that the lead aircraft cannot see the formation except, possibly, during turns.

"Silent check-in" procedures are used; communications between aircraft are minimized. Everyone is expected to fly the mission exactly as planned according to time, position and event hacks, and to arrive at the drop zone at the pre-determined time of arrival. Silent check-in procedures increase the importance of exact compliance to the briefing. Nine segments of the mission are suggested for measurement.

Taxi. Formation aircraft are expected to taxi exactly on hack, and to maintain one aircraft length of nose-tail separation. Minimum, maximum and average scores are suggested for nose-tail position measurement. The number of thrust changes and breaking actions should describe a pilot's ability to perform the task with required "smoothness".

Take-off. The formation lines-up on alternate left and right sides of the runway. At the briefed time, the flight leader starts the take-off roll. Time of take-off roll initiation, centerline deviation (minimum, maximum and average), and rotation speed form the measurement set. For the number two aircraft, the desired take-off time is exactly 15-seconds behind the leader. Number three aircraft should accelerate 30-seconds behind the leader.

Join-up. For the lead aircraft, track deviation from the flight plan, airspeed and altitude (minimum, maximum and average) are suggested for measurement. The elements must assume their 2,000-foot, in-trail positions on the leader prior to acceleration time. For formation elements, minimum, maximum and average deviations from the flight track, average closing rate and time to join are suggested measures. Once the required position is obtained, station-keeping (spacing) measures (minimum, maximum and average range, bearing and altitude difference from the leader) completes the measurement set.

Acceleration. At a pre-briefed time, all aircraft accelerate to enroute speed and altitude using a power setting of 900^{0} Turbine Inlet Temperature (TIT). The time that thrust is set to 900^{0} TIT and spacing measures during acceleration complete the measure set.

In-Trail, enroute. For formation elements, the spacing measures are recommended. The lead aircraft should be flown smoothly and accurately. Measures shown for single ship airdrop from the IP to the slowdown point are appropriate for the lead aircraft on each enroute leg.

Slowdown point. In addition to single ship measures, the lead aircraft position relative to the slowdown point is recommended. For the number two and three aircraft, immediate application of thrust to flight idle at the radio call and spacing are the only additional measures required.

AIR DROP FORMATION

TAXI:

Time: _____ Nose-Tail Distance: (Min/Max/Avg)
Breaking: (# + Duration) Thrust: _____

TAKE OFF:

Time Behind Leader: _____ Centerline Dev.: _____
Rotation Speed: _____

JOINUP:

Lead: Pre-Briefed Track Dev.: _____ A/S: _____ Altitude: _____
Elements: Pre-Briefed Track: _____ Closing Rate: _____
Time to Join: _____ Join Prior to Accel. Time: _____
Spacing: Range/Brg/Δ Alt.

ACCELERATION:

Thrust (900^{0} ITI) Time: _____ Spacing: Range/Brg/Δ Alt.
(On Hack)

TRAIL: (Enroute)

Spacing: Range/Brg/Δ Alt. (Lead A/C Referenced)

SLOWDOWN POINT:

Lead: A/C Posn at Radio Call.
Elements: Thrust to Flt Idle at Radio Call.
Spacing: Range/Brg/Δ Alt.

DROP:

Spacing: Range/Brg/Δ Alt.: Relative to Lead's Track (DZ Axix)
Drop Score Adjusted for Lead's Posn Error.
Drop Score Adjusted for Formation Posn.

ESCAPE:

Spacing: Range/Brg/Δ Alt. (Lead A/C Ref)

RECOVERY:

Initial: Airspeed: _____ Altitude: _____
Spacing: Range/Brg/Δ Alt.
Pitchout: Roll: _____ Altitude: _____ Airspeed: _____
Time From Lead: _____
Downwind: Roll: _____ Airspeed: _____ Spacing: (Time From Lead)
Δ Alt.: _____ (Gear, Flaps)
Final: Roll: _____ Altitude at 1/4 mile: _____
Spacing: (Time From Lead)
Touchdown: Posn: (Alternate Side of Rnway)
Δ Time from Prior A/C: _____
V/V: <540, Airspeed: <139, Lead: Land Long
Power: (Flt Idle Until ∿ 3000' from end, then
Reverse, Brake)
Runway Range: (At above times)

Drop. From the slowdown point to the drop, spacing relative to lead's track should be measured. Formation aircraft drop scores should be adjusted for any position error of the lead aircraft, and for slight offsets brought about be ideal formation position.

Escape. The primary requirement is to follow the pre-briefed flight plan, maintaining spacing and accelerating to enroute speed and altitude.

Recovery. The formation recovery is a conventional 360^{o} overhead approach. Spacing and timing during the initial, pitchout, downwind, base and final approach segments should lead to an aircraft passing the end of the runway every 15-seconds. Measurement is similar to transition except that all aircraft are expected to roll to the end of the runway in an expeditious fashion. Current practice is to leave the power in flight idle until about 3,000-feet of runway remain, then reverse thrust and brake as necessary. Taxi-in is according to the same criteria as taxi-out.

RADAR NAVIGATION AND BOMBING

Radar is used for simple navigation, for low-level terrain avoidance and terrain following, and for bombing under low-visibility conditions. Each of these uses is discussed in the following paragraphs. Only the B-52 is equipped with terrain avoidance radar of the sample of six aircraft selected. The A-7D has terrain avoidance features in the forward looking radar with which it is equipped, but it does not permit operation below surrounding terrain features. Therefore, measurement for terrain avoidance has been tailored for the requirements of the B-52.

Radar navigation. Radar navigation is performed using a combination of information from ground-mapping radar, inertial systems, and dead reckoning. The objective is to pass over selected check-points at precise times, and in particular, to arrive at the Initial Point for the bombing run at the correct time. Therefore, at each check-point it is relevant to measure the time, and errors in distance along the track and across the track. After a turn it is common to be off the planned track due to improper bank angle and subsequently improper turn radius. Along each leg of the course it is of interest to record deviations from the centerline of the track, heading variations, airspeed changes, and altitude.

Bomb release conditions. Measurement for weapons delivery is quite similar to that discussed under ground attack. Weapons release will occur during level flight. Altitude, vertical velocity, bank angle, and sideslip are the basic error analysis factors. The aircraft heading, bearing and range to the target, are also important in determining the bomb fall line. In level

RADAR NAV. BOMB

RADAR NAV

Check Point	Track Dist. Error	Cross Track Dist. Error	Time Error	After Turn Lat.Dist	Leg	C/L Dev	Hdg	A/S	Radar Alt. Min Max
1	x	x	x	x	1	x	x	x	x
2	x	x	x	x	2	x	x	x	x
:					:				
IP	x	x	x	x	N	x	x	x	x

BOMB RELEASE COND.

Hdg: ______ Alt: ______ VV: ______ Bank: ______ Slip: ______

TGT Brng: ________ Range: ________ Wind: ________

OAP/TGT Designate Error: RNG _______ Brng _______

Weapon Deliv. Display Errors at Release: _____,_____,_____

Bomb Score: _____ / _____

TERRAIN AVOIDANCE*

INIT. Level-Off Alt: ______

Banks > 12°: _____ Δ Hdg > 10°: _____ # Banks > 30°: _____

Parameter	TIME <Tol.A	<Tol.B	<Tol.C	>Tol.C	Min	Max
HDG	x	x	x	x	x	x
A/S	x	x	x	x	x	x
Track Dev	x	x	x	x	x	x

Parameter	Number of Scans 1	2	3	4	5	6	7	..	..
Plan Return (< 1/8', <3 mi)	x	x	x	x	x	x	x		
Prof Return (<1/2", Above HRL)	x	x	x	x	x	x	x		
Bank Angle >12°	x	x	x	x	x	x	x		
Radar Alt. After Dropout (Min/Max)	x/x	x/x	x/x	x/x	x/x	x/x	x/x		

B-52 & A7D	LEG 1	2	3	4	5
Min Radar Alt	x	x	x	x	x
Max Radar Alt	x	x	x	x	x
ADI Dev. (A7D only)	x	x	x	x	x

*Tailored to B-52 Requirement

flight the aircraft will be crabbing into the wind, which should create proper conditions for bomb fall to the target, compensating for the effects of wind. Given a HUD display for weapons delivery, or the equivalent, performance with respect to tracking display errors should be measured. If a weapon is released against a radar-reflecting target on the range, a bomb score will also be available. If, additionally, the bomb run is made using an offset aim point, proper designation of the offset aim point should be measured.

Terrain avoidance. In the following paragraphs, terrain avoidance is discussed primarily in terms of B-52 equipment. At the start of a terrain avoidance run, a descent is made to the proper altitude; it is obviously very important to level off at the correct altitude, and especially to avoid descending down through the assigned altitude. The B-52 radar scans in a horizontal plane, without great error for bank angles up to 12°. Therefore, banks greater than 12° must be avoided unless control of the flight is assumed by the navigator. In any case, banks greater than 30° indicate emergency maneuvering with some danger; heading changes in excess of 10° indicate bad technique.

During each leg, heading, airspeed, and track should be maintained. Tolerances may be established to correspond with scores of highly qualified, qualified, conditionally qualified, and unqualified.

Two basic types of radar returns can be used. One is a Plan Display indicating terrain features which are higher than a pre-set clearance plane, presenting this information in a PPI format. The other is a Profile display, showing the profile of the terrain ahead of the aircraft, much as it would appear through a window; a line across the 'scope represents the clearance plane. In the plan mode, as the flight path of the aircraft is elevated, returns will diminish in size and eventually disappear. When a peak ahead will be cleared by just the proper clearance altitude, it will appear as a small return, or "tick". In the profile mode, the profile will simply lower on the 'scope until the highest terrain point ahead is below the clearance plane line.

The criteria for clearance are specified in terms of the number of radar scans which ensue before an obstacle ahead of the aircraft is brought down to the clearance plane by climbing the aircraft. Thus, plan returns directly ahead must be reduced to the "Ticking" level, while profile returns must be below the clearance plane, within N scans. Since the task is to follow the contour of the terrain, altitude must be reduced so that clearance altitude is not excessive; greatest clearance altitude is likely to occur after passing over a high obstacle, unless a descent is properly timed. Consequently, radar altitude after a return "drops out" is of interest, as well as minimum and maximum radar altitude for each leg of the course flown. The A-7D presents commands on the Attitude Director Indicator; deviations on this display may also be measured.